




## A TEXT-BOOK

OF

## MINERALOGY.

WITH AN EXTENDED TREATISE ON

## CRYS'TALLOGRAPHY AND PHYSICAL MINERALOGY.

3Y<br>EDWARD SALISBURY DANA, CURATOR OF MINERALOGY, YALE COL1.EGE.<br>ON THE PLAN AND WITH THE CO-OPERATION<br>OF<br>PROFESSOR JAMES D. DANA.<br>WITH UPWARDS OF EIGHT HUNDRED WOODCUTS AND ONE COLORED PLATE.

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## PREFACE.

The preparation of a "Text-Book of Mineralogy" was undertaken in 1868, by Prof. J. D. Dana, immediately after the publication of the fifth edition of the System of Mineralogy. The state of his health, however, early compelled him to relinquish the work, and he was not able subsequently to resume it. Finally, after the lapse of seven years, the editorship of the volume was placed in the hands of the writer, who has endeavored to carry out the original plan.

The work is intended to meet the requirements of class instruction. With this end in view the Descriptive part has been made subordinate to the more important subjects embraced under Physical Mineralogy.

The Crystallography is presented after the methods of Naumann; his system being most easily understood by the beginner, and most convenient for giving a general knowledge of the principles of the Science. For use in calculations, however, it is much less satisfactory than the method of Miller, and a concise exposition of Miller's System has accordingly been added in the Appendix. The chapter on the Physical Characters of Minerals has been expanded to a considerable length, but not more than was absolutely necessary in order to make clearly intelligible the methods of using the principles in the practical study of crystals. For a still fuller discussion of these subjects reference may be made to the works of Schrauf and of Groth, and for details in regard to the optical characters of mineral species to the Mineralogy of M. DesCloizeaux.

The Descriptive part of the volume is an abridgment of the System of Mineralogy, and to that work the student is referred for the history of each species and a complete list of its synonyms; for an enumeration of observed crystalline planes, and their angles; for all published analyses;
for a fuller description of localities and methods of occurre ace, and also for an account of many species of uncertain character, not mentioned in the following pages. A considerable number of changes and additions, howover, have been made in the preparation of the present work, made necessary by the progress in the Science, and among these are included many new species. The chemical formulas are those of modern Chemistry. The new edition of Rammelsberg's Handbuch der Mineralchemie has been often used in the preparation of the volume, and frequent references to him will be found in the text.

The work has throughout been under the supervision of Prof. Dana, and all the proofs have passed under his eye. Acknowledgments are also due to Prof. G. J. Brush and Prof. J. P. Cooke for friendly advice on many points.

## PREFACE TO THE REVISED EDITION.

In this Revised Edition, the chief additions are contained in four supplementary chapters, covering about fifty pages. Of these, two are devoted to descriptions of new instruments and methods of research in Crystallography and Physical Mineralogy; and the others to brief descriptions of the minerals recently announced, and a concise statement of important new facts in regard to the characters or occurrence of old species. A number of new figures are introduced in illustration of these subjects. The work has been repaged ; and a new index, much more complete than the former one, has been added.

New Haven, January, 1883.

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## INTRODUCTION.

Trie Third Kingdom of Nature, the Inorganic, embraces all species nut organized by living growth. Unlike a plant or animal, an inorganic species is a simple chemical compound, possessing unity of chemical and physical nature thronghout, and alike in essential characters throngh all diversity of age or size.

The Science of Mineralogy treats of those inorganic species which occur ready formed in or about the carth. It is therefore but a fraginent of the Science of Inorganic nature, and it owes its separato consideration simply to convenience.

The Inorganic Compounds are formed by the same forces, and on the same principles, whether produced in the laboratory of the chemist or in outdoor nature, and are strictly no more artificial in one case than in the other. Calcium carbonate of the chemical laboratory is in every character the same identical substance with calcium carbonate, or calcite, found in the rocks, and in each case is evolved by nature's operations. There is hence nothing whatever in the character of mineral species that entitles them to constitute a scparate division in the natural classification of Inorganic species.

The objects of Mineralogy proper are three-fold : 1, to present the true idea of each species ; 2, to exhibit the means and methods of distinguishing species, which object is however partly accomplished in the former ; 3, to make known the modes of occurrence and associations of species, and their geographical distribution.

In presenting the science in this Text Book, the following order is adopted :
I. Physical Mineralogy, comprising that elementary discussion with regard to the structure and form, and the physical qualities essential to a right understanding of mineral species, and their distinctions.
II. Ciemical and Determinative Mineralogy, presenting briefly the general characters of species considered as chemical compounds, also giving the special methods of distinguishing species, and tables constructed for this purpose. The latter subject is preceded by a few words on the use of the blow-pipe.
III. Descriptive Mineralogy, comprising the classification and descriptions of species and their varieties. The descriptions include the physical and chemical properties of the most common and important of the minerals,
with some account also of their association and geographical distribution. The rarer species, and those of uncertain composition, are only very briefly noticed.

Besides the above, there is also the department of E'conomic Miner alogy, which is not here included. It treats of the uses of minerals, (1) as ores; (2) in jewelry; and (3) in the coarser arts.

The following subjects connected with minerals properly pertain to Geology : 1, Lithulogical geology, or Lithology, which treats of minerals as constituents of rocks. 2, Chemical geology, which considers in one of its subdivisions the origin of minerals, as determined, in the light of chemistry, by the associations of species, the alterations which species are liable to, or which they are known to have undergone, and the general nature, origin, and changes of the earth's rock formations. Under chemical geology, the department which considers especially the associations of species, and the order of succession in such associations, has received the special name of the paragenesis of minerals; while the origin of minerals or rocks through alteration, is called metamorphism or psoudomorphism, the latter term being restricted to those cases in which the crystalline form, and sometimes also the cleavage, of a mineral is retained after the change.

## LITERATURE.

For a catalogue of mineralogical works, and of periodicals, and transactions of Scientific Societies in which mineralogical memoirs have been and are published, reference is made to the System of Mineralogy (1868), pp. xxxv-xlv., Appendix II. (18i4), and Appendix III. (1882). The following works, however, deserve to be mentioned, as they will be found usetul as books of reference.

## In Crystallography :

Naumann. Lehrbuch der reinen und angewandten Krystallographie. 2 vols., 8vo. Leipzig, 18:9.

Naumann. Anfangsgrunde der Krystallographie. $2 d$ ed., 292 pp., 8vo. Leipzig, 1854.
Naumann. Elementeder theoretischen Krystallographie. 883 pp., 8vo. Leipzig, 1856.
Miller. A Treatise on Crystallography. Cambridge, 1839.
Grailich. Lehrbuch der Krystallographie von W. H. Miller. 328 pp., Svo. Vienna, 1856.
Kopp. Einleitung in die Krystallographie. 348 pp., 8 vo. Braunschweig, 1862.
Von Lang. Lehrbuch der Krystallographic. 358 pp., 8vo. Vienna, 1866,
Quenstedt. Grundriss der bestimmenden und rechnenden Krystallographic. Tübingen, 1873.

Rose-Sadebeck. Elemente der Krystallographie. Ed ed., vol. i., 181 pp., 8vo. Berlin, 1873. Vol. ii., Angewandte Krystallographic. 284 pp., 8vo. Berlin, 1876.

Schrauf. Lehrbuch der Physikalischen Mineralogic. Vol. i., Krystallographic. 251 pp., 8 vo., 1866 ; vol. ii., Dic angewandte Physik der Kirystalle. 426 pp. Vienna, 1868.

Groth. Physikalische Krystallographic. 527 pp., 8vo. Leipzig, $18 i 6$.
Klein. Einleitung in die Krystallberechnung. 39:3 pp., \&vo. Stuttgart, 1876.
Mallard. Traité de Cristallographie géometrique et physique, vol. i. Paris, 1876.
Bauerman. Text-Book of Systematic Mineralogy. Yol. i, $267 \mathrm{pp}, 12 \mathrm{mo}$. London. 1881.

Liebisch. Geometrische Krystallographic. 464 pp., 8vo. Leipzig, 1881.
Tschermak. Lehrbuch der Mineralogie. Lief. 1., II., pp. 1-308. Vienna, 18\$1-82.
In Physical Mineralogy the works of Schrauf (1868), and Groth (1876), and Tichermak, titles as in the above list. Reference is also made to the works on Physies, mentioned on p. 160. In addition to these, on pp. 111, 12: , 160, 167, 171, 190, a few memoirs of especial importance on the different subjects are enumerated.

In Chemical Mineralogy : Rammelsberg,.Handbach der Mineralchemic, ad ed., Leipzig, 1875. In Determinative Mineralogy, Brush, New York, $18 \% 8$.

In Descriptive Mineralogy : among recent works those of Brooke and Miller (2d ed. of Phillips' Min.), London, 1852 ; Quenstedt, 3d ed, Tübingen, 18i7; Schrıuf, Atlas der Krystallformen, Lief. I.-V., 1871-1878; Groth (Tabellarische Uebersicht der Mineralien, etc.), $2 d$ ed., 1882 ; v. Kokscharof, Materialien zur Nineralogie Russ'ands, vol. i., 1865, vol. viii., 1881 ; Des Cloizeaux, vol. i., 1862, vol. ii., Paris, 18.4 ; Dana, System of Mineralogy, 1898, App. I., 1872, Аpp. II., 1874, Аpp. III., 1:82; Blum, 4th ed., 1874 ; Nau-mann-Zirkel, 11th ed., 1881.

The foilowing publications are devoted particularly to Minera'ogy :
Jahrbuch für Mineralogie ; G. Leonhard and H. B. Geinitz, Editors ; after 1879, E. W. Benecke, C. Klein, and H. Rosenbusch.

Mineralogische Mittheilungen ; commenced 1872, G. Tschermak, Editor ; since 1878, published as the Mineralogische und Petrographische Mittheilungen.

Mineralogical Magazine and Journal of the Mineralogical Society ; London, and Truro, Cornwall. Commenced 1875.

Zeitschrifit für Krystallographic ; P. Groth Editor ; Leipzig. Commenced 18 6. 6.
Bulletin de la Société Mineralogique de France. Commenced 1878.

## ABBREVIATIONS.

For abbreviations of the names of Mineralogical works, of Journals, publications of Scientific Societies, etc., see System Min., 5th ed., pp. xxxv.-xlv., App. III., p. viii.

The following abbreviations are used in the Description of Species.

| B.B. | Before the Blowpipe (p. 210). | Obs. | Observations on occurrence, etc. <br> Comp. |
| :--- | :--- | :--- | :--- |
| Composition. | O.F. | Oidizing Flame (p. 204). |  |

In asterisk (*), appendel to the name of a mineral species in the Descriptive part of th's work, indicates that additinal facts in regard to it are mentioned in the Supplementary Ouspter, pp. 420 to 440.

## PARTI. <br> PHYSICAL MINERALOGY.

The grand departments of the science here considered are the following: 1. Structure.-Structure in Inorganic nature is a result of mathematical symmetry in the action of cohesive attraction. The forms produced are regular solids called crystals ; whence morphology is, in the Inorganic kingdom, called crystallology. It is the science of structure in this king. dom of nature.
2. Pirysical properties of Minerals, or those depending on relations to light, heat, electricity, magnetisın ; on differences as to density or specific gravity, hardness, taste, odor, etc.

Crystallology is naturally divided into, I. Crystallograpiry, which treats of the forms resulting from crystallization; II. Crystallogeny, which describes the methods of making crystals, and discusses the theories of their origin. Only the former of these two subjects is treated of in this work

## SECTION I.

## CRYSTALLOGRAPHY.

Crystallography embraces the consideration of-(1) normally formed or regular crystals; (2) twin or compound crystals ; (3) the irregularities of crystals ; (4) crystaliine aggregates; and (5) pseudomorphous crystals.

## 1. General Characters of Crystals.

(1) E.cternal form.-Crystals are bounded by plane surfaces, called simply planes or faces, symmetrically arranged in reference to one or more diametral lines called axes. In the an= nexed figure the planes 1 and the planes $i$ are symmetrically arranged with reference to the vertical axis $c c$; and also the planes of each kind with reference to the three transverse axes.
(2) Constancy of angle in the same species. -The crystals of any species are essentially constant in the angle of inclinatic: betweon like planes. The angle between 1 and $i$, in a given species, is always cssertially the same, wherever the crystal is found, and whether a product of nature or of the laboratory.
(3) Difference of angle of different species.-The crystals of different species commonly differ in angles between corresponding planes. The angles of crystals are consequently a means of distinguishing species.
(4) Diversity of planes.-While in the crystals of a given species there is constancy of angle between like planes, the forms of the crystals may be exceedingly diverse. The accompanying figures are examples of a few of

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3


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the forms of the species zireon. There is hardly any limit to the number of forms which may oceur ; yet for each the angles between like planes are essentially constant.

Crystals occur of all sizes, from the merest microscopic point to a yard or more in diameter. A single crystal of quartz, now at Milan, is three and a quarter feet long, and five and a half in circumference ; and its weight is estimated at eight hundred and seventy pounds. A single cavity in a vein of quartz near the Tiefen Glacier, in Switzerland, discovered in 1867, has afforded smoky quartz crystals weighing in the aggregate about 20,000 pounds ; a considerable number of the single crystals having a weight of 200 to 250 pounds, or even more. One of the gigantic beryls from Acworth. New Hampshire, measures four feet in length, and two and a half in circumference; and another, at Grafton, is over four feet long, and thirty-two inches in one of its diameters, and does not weigh less than two and a half tons. But the highest perfection of form and transparency are found only in crystals of small size.

In its original signification the term crystal was applied only to crystals of quartz (f. 1), which the ancient philosophers believed to be woater congealed by intense cold. Hence the term, from кри́лталлоs, ice.
(5) Symmetry in the position of planes.-The planes on the crystals of any species, however numerons, are arranged in accordance with certain laws of symmetry and numerical ratio. If one of the simpler forms be taken as a primary or fundamental form, all other planes will be secondary planes, or modifications of the fundamental form. It should be observed, however, that the forms called primary and fundamental in crystallographic description, are in general merely so by assumption and for convenience of reference. (See also p. 12.)

Cleavage.-Besides external symmetry of form, crystall zation produces also regularity of internal structure, and often of fracture. This regularity of fracture, or tendency to break or cleave along certain planes, is called cleavage. The surface afforded by cleavage is often smooth and brilliant. The directions of cleavage are those of least cohesive iorce in a crystal ; it
is not to be understood that the clearage lanellæ are in any sense present before they are made to appear by fracture.

In regard to cleavage, two principles may be here stated:-(a).In any species, the direction in which cleavage takes place is always parallel to some plane which either actnally occurs in the crystals or may exist there in accordance with the general laws which will be stated hereafter.
(b) Cleavage is uniform as to ease parallel to all like planes ; that is, if it may be obtained parallel to one plane of a kind (as $1, f .1$ ), it may be ob)tained with equal facility parallel to each of the other planes 1 ; and will afford planes of like lnstre. This is in accordance with the symmetry of crystallization. It will be evident from this that the angles between planes of like cleavage will be constant: thus, a nass of calcite under the blow of a hammer will separate into conntless rhombohedrons, each of which affords on measurement the angles $74^{\circ} 55^{\prime}$ and $105^{\circ} 5^{\prime}$. In a sliapeless mass of marble the minute grains have the same regularity of cleavage structure. See further, p. 119.

## 2. Descriptions of some of the simpler forms of Crystals.

Preliminary Definttions. Angles.-In the descriptions of crystals three kinds of angles may come under consideration, solid, plane, and interfacial. The last are the inclinations between the faces or planes of crystals.

Axes.-The crystallographic axes are imaginary lines passing throngh the centre of a crystal. They are assumed as axes in order to describe, by reference to them, the relative positions of the different plancs. One of the axes is called the vertical, and the others the lateral; the number of lateral axes is either two or three. The axes have essentially the same relative lengths in all the crystals of a species; but those of different species often differ widely

Diametral planes.-The planes in which any two axes lie are called the axial or dianetral planes or sections; they are the coördinate planes of analytical geometry. They divide the space about the centre into sectants; into eight sectants, called octants, if there are but two lateral axes, as is generally the case ; but into twelve sectants if there are three, as in hexagonal crystalline forms.

Diagonal planes are either diagonal to the three axes, as those throngh the centre connecting diagonally opposite solid angles of a cube, or diagonal to two axes, and passing throngh the third, as those connecting diagomally opposite edges of the cube.

Similar planes and edges are such as are similar in position, and of like angles with reference to the axes or axial planes. Moreover, in the case of similar edges, the two planes by whose intersection the edges are formed, meet at the same angle of inclination. For example, all the planes and edges of the tetrahedron (f. 9), regular octahedron (f. 11), cube (f. 14), rhorshic dodceahedron (f. 19), are similar. In the rhombohedron (f. 16) there are two sets of similar edges, six being obtnse and six acute.

Sotid angles are similar when alike in plane angles each for each, and when formed by the meeting of planes of the same kind.

A combination-edge is the edge formed by the meeting or intersection of two planes.

Truncations, bevelments.-In a crystal, an edge or angle is said to be replaced when the place of the edge or angle is occupied by one or more planes; and in the case of the replacement of an edge, the replacing planes make parallel intersections with the including planes, that is, with the direction of the replaced edge (f. 43).

A replacement of an edge or angle is a truncation when the replacing plane makes equal angles with the including planes. Thus, in f. 6. $i-i$ truncates the edge between $I$ and.I.

An edge is said to be bevelled when it is replaced by two similar planes, that is, by planes having like inclinations to the adjoining planes. Thus, in $f .5$, the edge between 3,3 , is bevelled by the two planes $3 \cdot 3,3-3$, the right $3-3$ and 3 having the same mutual inclination as the left $3-3$ and 3 . So, in f .192 , p. 43, the edge between $I$ and $I$ is bevelled by the planes $i-\overline{2}, i-\overline{2}$. Truncations and bevelments of edges take place only between similas planes. Thus $I, I$, and 3,3 , are similar planes in fig. 5 . The edge $1 \mid 1$ might be truncated or bevelled, for the same reason; but not the edge between 1 and $I$, since 1 and $I$ are dissimilar planes.

A zone is a series of planes in which the combination-edges or mutual intersections are parallel. Thus, in fig. 3 , the planes $1,3, I$ make a vertical zone; so in $f .8$, the planes between 1 and $i-i$ make a zone, and this zone actually continues above and below, around the crystal ; in $f .5$, the plants $3,3-3,3-3,3$ are in one zone ; and $i-i, I, i-i, I$, in another. On the true meaning of zones, see p. 53.

The above explanations are preliminary to the descriptions of the forms of all crystals.


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A. - Formis contained under four mqual triangular planes.-A. Regular tetrahedron (f. 9). Edges six ; solid angles four. Faces equilateral triangles, and plane angles therefore $60^{\circ}$. Interfacial angles $70^{\circ} 31^{\prime} 44^{\prime \prime}$. Named from tétpakıs, four times, and ěè $\rho a$, face.
2. Sphenoid (f. 10). Faces isosceles triangles, not equilateral. Plane and interfacial angles varying; the latter of two kinds, (a) two terminal, (b) four lateral. Named from $\sigma \phi \dot{\phi} \nu, a$ wedge.
B.-Forms contained undier eight triangular planes.-The solids here included are called octahedrons, from öктакьs, eight times, and éסра, face. They have twelve edges; and six solid angles. One of the axes, when they differ in length, is made the vertical axis; and the others are the lateral axes. The solid angles at the extremities of the vertical axes are the vertical or terminal solid angles; the other forr are the lateral. The four edges meeting in the apex of the terminal solid angle are the terminal edges; the others, the lateral or basal edges.

1. hegular Octahedron (f.11). Faces equilateral triangles. Interfacial angles $109^{\circ} 28^{\prime} 16^{\prime \prime}$; angle between the planes over the apex of a solid angle $70^{\circ} 31^{\prime} 44^{\prime \prime}$; angle between edges over a solid angle $90^{\circ}$. The three axes are equal, and hence either may be made the vertical. Lines connecting the centres of opposite faces are called the octahedral or trigonal inter.
axts ; and those connecting the centres of opposite edges the dodecithedral or rhombic interaxes.
2. Square Octahedron (f. 12, f. 12^). Faces equal isosceles triangles, not equilateral. The four terminal edges are equal and similar; and se also the four lateral.


The lateral axes are equal; the vertical axis may be longer or shorter than the lateral.
3. The rhombic octahedron (f. 13) differs from the square octahedron in having a rhombic base, and consequently the three axes are unequal. The basal edges are equal and similar; but, owing to the unequal lengths of the lateral axes, the terminal edges are of two kinds, two being shorter and more obtuse than the other two.
C.-Forms contained under six equal planes.-The forms here included have the planes parallelograms; the edges are twelve in number and equal ; the solid angles eight.

1. Cube (f. 14). Faces equal squares, and plane angles therefore $90^{\circ}$. The twelve edges similar as well as equal ; the eight solid angles similar' and equal. Interfacial angles $90^{\circ}$. The three axes equal and intersecting at right angles.

Lines connecting the apices of the solid angles are the octahedral or trigonal interaxes, and those connecting the centres of opposite edges the dodecahedral or rhombic interaxes. If the cubic axis (=edge of the enbe) $=1$, then the dodecahedral interaxes $=\sqrt{2}=1.41421$; and the octahedral interaxes $=\sqrt{3}=1.73205$. And if the dodecahedral axis $=1$, then the octahedral $=1.224745$.


If a cube is placed with the apex of one angle vertically over that diagonally opposite, that ls, with an octahedral interaxis vertical, the parts are all symmetrically arranged around tnis vertical axis. In this position (f. 15) the cube has three planes inclined toward one apex, and three toward the other; it has three terminal edges meeting at each apex; and six lateral edges situated symmetrically, but in a zigzag, around the vertical axis. If lines are drawn connecting the centres of the opposite lateral edges, and these are taken as the lateral axes, the lateral axes, three in number, will lie in a plane at right angles to the vertical, and will intersect at the centre at angles of $60^{\circ}$. The cube placed in this position would then have
one vertical and three equal lateral axes; and as the lateral axas correspond to the dodeca hedral interaxes of a cube, the ratio of a lateral axis to the vertical is 1:1.224745.
2. Rhombohedron (f. 16 to 18). Faces equal rhombs. The twelve edgea of two kinds; six obtuse, and six acute. Solid angles of two kinds ; two symmetrical, consisting each of three equal plane angles; the other six unsymmetrical, the plane angles enclosing them being of two kinds.

The rhombohedron resembles a cube that has been either shortened, or lengthened, in the direction of one of the octahedral axes, the former making an obtuse rhombohedron, the latter an acute; and it is in position when this axis is vertical, the parts being situated symmetrically about this axis, as in the second position of the cube above described. In an obtuse rhombohedron ( $f .16,17$ ), the terminal solid angles are bounded by three obtuse plane angles, and the other six, which are the lateral, by two acute and one obtuse ; the six terminal edges (three meeting at each apex) are obtuse, and the six lateral edges are acute. Conversely, in an acute rhombohedron (f. 18) the terminal angles are made up of acute plane angles, and the lateral of two obtuse and one acute; the six terminal cdges are acute, and the six lateral obtuse. The axes are a vertical, and three lateral; the lateral axes connect the centres of opposite lateral edges and intersect at angles of $60^{\circ}$.

The cube in the second position (f. 15) corresponds to a rhombohedron of $90^{\circ}$, or is intermediate between the obtuse and the acute series.
D.-Forms contained under twelve equal planes. 1.
 Rhombic Dodecahedron (f. 19). Faces rhombs, with the plane angles $109^{\circ} 28^{\prime} 16^{\prime \prime}, 70^{\circ} 31^{\prime} 44^{\prime \prime}$. Edges twenty-four, all similar; interfacial angle over each edge $120^{\circ}$. Solid angles of two kinds: (a) six acute tetrahedral, being formed of four acute plane angles; and (b) eight obtuse trihedral, being formed of three obtuse plane angles. Angle between planes over apex of tetrahedral solid angle, $90^{\circ}$; angle between edges over the same $109^{\circ} 28^{\prime} 16^{\prime \prime}$. The axes three, equal, rectangular, and therefore identical with those of the regular octahedron and cube. The dodecahedral interaxes connect the centres of opposite faces; and the octahedral the apices of the trihedral solid angles. Named


2. Pyramidal dodecahedron, or Quartzoid. (Called also Dihexagonal Pyramid, Isosceles Dodecahedron.) Faces isosceles triangles, and arranged in two pyramids placed base to base (f. 20). Edges of two kinds: twelve equal terminal, and six equal basal; axes, a vertical differing in length in different species; and three lateral, equal, situated in a plane at right angles to the vertical, and intersecting one anuther at angles of $60^{\circ}$, as in the rhombohedron.
E.-Prisms. - Prismatic forms consist of at least two sets of planes, the basal planes being unlike the lateral. The bases are always equal ; and the lateral planes parallelograns. The vertical axis is unequal to the lateral. (a) Three-sided prism. A right (or erect) prism, having its bases equal equilateral triangles. (b) Four-sided prisms. Four sided prisms are cither right (erect), or oblique, the former having the vertical axis
at right angles to the base or to the plane of the laieral axes, and the latter oblique.

1. Square or Tetragonal Prism (f. 21, 22). Base a square ; lateral planes equal. Edges of two kinds : (a) eight basal, equal, each contained between the base and a lateral plane ; ( $b$ ) four lateral, contained between the equal lateral planes. Interfacial angles all $90^{\circ}$, plane angles $90^{\circ}$. Solid angles eight, of one kind. Axes : a vertical, differing in. length in different species, and longer or shorter than the lateral ; two lateral, equal, at right angles to one another and to the verfical, and connecting either the centres of opposite lateral planes (f.21) or edges (f. 22). The cube is a square prism with the vertical axis equal to the lateral.

2. Right Rhombic Prism (f. 23). Base a rhomb; lateral planes equal parallelograms. Edges of three kinds : (a) eight basal, equal, and rectangular as in the preceding form; (b) two lateral, obtuse; and (c) two lateral, acute. Solid angles of two kinds : (a) obtuse at the extrenities of the ob tuse edge, and $(\bar{b})$ acute at the extremities of the acnte edge. Axes rectangular, unequal ; a vertical ; a longer lateral, the macrodiagonal axis (named from $\mu \dot{\kappa} \kappa \rho о s$, large), and a shorter lateral, the brachydiagonal axis (named from $\beta$ paxús, short).
3. Right Rectangular Prism (f. 24). Base a rectangle, and in consequence of its unequal sides, two opposite lateral planes of the prism are broader than the other two. Edges all rectangular, but of three kinds : (a) four longer basal ; (b) four shorter basal ; (c) four lateral. Axes connecting the centres of opposite faces, rectangular, unequal; a vertical, a macrodiagonal, and a brachydiagenal, being like those of the right rhombic prism. In the rectangular prism, either of the faces may be made the basal, and either axis, consequently, the vertical.
4. Oblique Prisms. Figs. 25 and 26 represent prisms oblique in the direction of one axis. As seen in them, the vertical axis $c$ is oblique to the lateral axis $\dot{a}$, called the clinodiagonal axis ; but $b$, the orthodiagonal axis, is at right angles to both $c$ and $\dot{a}$. Similarly, the axial sections $c b, b a$ are mutually oblique in their inclinations, while $c a, c b$ and $c a, b a$ are at right angles. The clinodiagonal section $c a$ is called the section or plane of symmetry.

The form in f .25 is sometimes called an obiique rhombic prism. The edges are of two kinds as to length, but of four kinds as to interfacial angles over them: (a) four basal obtuse; (b) four basal acute ; (c) two lateral obtuse: (d) two lateral acute. The prism is in position when placed with the clinodiagunal section vertical.

Figs. 27 and 28 show the doubly oblique, or oblique rhomboidal prism, in which all the axes, and hence all the axial sections, are oblique to each
other. All these cases will receive further attention in the description of actual crystalline forms.


The prisus (in f. 21, 24, 26, 28) in which the planes are parallel to the three dianetral sections, are sometimes called diametral prisms. This term also evidently includes the cube. The planes which form these diametral prisms are often called pinacoids. The terminal plane is the basal pinacoid, or simply base; also, in f. 24 the plane (lettered $i-i$ ) parallel to the macrodiagonal section is called the mucropinacoid, and the plane ( $i-\frac{\imath}{)}$ ) parallel to the brachydiagonal the brachypinacoid. In f. 26 the plane $(i-i)$ parallel the to orthodiagonal section is called the orthopinacoid, and the plaue ( $i-i$ ) parallel to the clinodiagonal section the clinopinacoid. The word pinacoid is from the Greek $\pi i v a \xi$, a board.
(c). Six-sided Prism.-The Hexagonal prism.
 Base an equilateral hexagon. Edges of two kinds: (a) twelve basal, equal and similar, (b) six lateral, equal and similar ; interfacial angle over the former $90^{\circ}$, over the latter $120^{\circ}$. Solid angles, twelve, similar. Axes: a vertical, of different length in different species; three lateral equal, intersecting at angles of $60^{\circ}$, as in the rhombohedron, and the dihexagonal pyramid or quartzoid, connecting the centres either of the lateral edges (f. 29): or lateral faces (f. 30).

## 3. Systems of Crystallization.

The systems of crystallization are based on the mathematical relations of the forms; the axes are lines assumed in order to exhibit these relations, they mark the degree of symmetry which belongs to each group of forms, and which is in fact the fundamental distinction between them. The number of axes, as has been stated, is either three or four-the number being four when there are three lateral axes, as occurs only in hexagonal forms.

Among the forms with three axes, all possible conditions of the axes exist both as to relative lengths and inclinations; that is, there are (as has been exemplified in the forms which have been described), (A) aniong orthometric kinds, or those with rectangular axial intersections; (a) the three axes equal ; (b) two equal, and the other longer or shorter than the two; (c) the three unequal ; and ( B ) among clinometric kinds, one or more of the intersections may be oblique (in all of these the three axes are unequal). The systems are then as follows:
A. Axes three; orthometric.

1. Isometric System.-Axes equa ${ }^{\circ}$. Examples, cube, regular octahe diron, rhombis: dodecahedron
2. Tetragonal System.-Lateral axes equal ; the vertical a rarying axis Ex., square prism, square octahedron.
3. Orthoriombic System.-Axes unequal. Ex., right rhombic prism, rectangular prism, rhombic octahedron.
B. Axes three ; clinometric.
4. Monoclinio System.-Axes unequal; one of the axial intersection oblique, the other two rectangular. Ex., the oblique prisms (f. 25, 26).
5. Triclinic System.-Axes unequal ; three of the axial intersections oblique. Ex., oblique rhomboidal prism (f. 27, 28).
C. Axes four.--Hexagonal System.-Three lateral axes equal, intersecting at angles of $60^{\circ}$. The vertical axis of variable length. Example, hexagonal prisms (f. 29, 30).

The so-called Diclinic system (two oblique axes) is not known to occur, for the single sub. stance, an artificial salt, supposed to crystallize in this system has been shown by von Zepharovich to be triclinic. Moreover, von Lang, Quenstedt, and others have shown mathematically that there can be only six distinct systems.

The six systems may also be arranged in the following groups:

1. Isometric (from ïбos, equal, and $\mu$ étpov, measure), the axes being all equal ; including: I. Isometrio System.
2. Isodiametric, the lateral axes or diameters being equal ; including: II. Tetragonal System; III. Hexagonal System.
3. Anisometric (from ävıoos, unequal, etc.), the axes being unequal ; including: IV. Orthorhombic System; V. Monoclinic System; VI. Triclinio System.

A further study of these different systems will show that in group 1 the erystals are formed or developed alike in all three axial directions; in group 2 the development is alike in the several lateral directions, but unlike vertically; and in group 3 the crystals are formed unlike in all three directions. These distinctions are of the highest importance in relation to the physical characters of minerals, especially their optical properties, and are often referred to beyond.

The numbers (in Roman numerals) here connected with the names of the system are often used in place of the names in the course of this Treatise.

The systems of crystallization have been variously named by different authors, as follows :

1. Isometric. Tessular of Mohs and Haidinger ; Isometric of Hausmann ; Tesseral of Naumaun; Regular of Weiss and Rose; Cubic of Dufrenoy, Miller, Des Cloizeaux; Monometric of the earlier editions of Dana's System of Mineralogy.
2. Tetragonal. Pyramidal of Mohs; Viergliedriege, or Zwei-und-einaxige, of Weiss; Tetragonal of Naumann ; Monodimetric of Hausmann ; Quadratic of von Kobell ; Dimetric of early editions of Dana's System.
3. Hexagonal. Rhombohedral of Mohs; Sechsgliedrige, or Irei-und-einaxige of Weiss; Hexagonal of Naumann ; Monotrimetric of Hausmann.
4. Orthoniombic. Prismatic, or Orthotype, of Mohs; Ein-und-einaxige of Weiss; Rhombic and Anisometric of Naumann; Trimetric and Orthorlombic of Hausmann; Trimetric of earlier editions of Dana's System.
5. Monoclinic. Hemiprismatic and Hemiorthotype of Mohs; Zwei-und-singliederige of Weiss; Monoclinohcdral of Naumann ; Ctinorhombic of v. Kobell, Hausmann, Des Cloizcaux; Augitic of Haidinger; Oblique of Miller; Monosymmetric of Groth.
6. Triclinic. Tetarto-prismatic of Mohs; Ein-und-eingliederige of Weiss; Triclinohedral of Naumann; Clinorhomboidal of v. Kobell; Anorthic of Haidinger and Miller; Anorthic, os Thoubly Oblique, of Des Cloizeaux ; Asymmetric, of Groth.

## 4. Laws with reference to the planes of Crystals.

The laws with reference to the positions of the planes of crystals are two: first, the law of simple mathematical ratio; secondly, the law of symmetry.

## 1. The Law of simple Mathematical Ratio.

The crystallographic axes afford the means, after the methods of analytical geometry, of expressing with precision the relative positions of the planes of crystals, and so exhibiting the mathematical ratios pertaining to crystallization. These axes, as has been stated, are supposed to pass through the centre of the crystal, and every plane must intersect one, two, or three of them. The position of a plane is obviously determined by the position
 of the points in which it meets these axes. Thus the plane ABC, f. 31, meets the three axes at the points A, B, and C, and its position is determined by the distances $\mathrm{O} \mathrm{A}, \mathrm{O} \mathrm{B}, \mathrm{O} \mathrm{C}$, intercepted between these points and the centre $O$. Similarly the plane ABD meets the axes in the points $\mathrm{A}, \mathrm{B}$, and D , and its position is determined by the distances $\mathrm{OA}, \mathrm{OB}, O \mathrm{D}$; and in the same manner with any other plane. On the crystals of a given species the occurring planes have exact numerical relations to each other, and it is to show these relations that certain lengths of the axes are assumed as units. Thus, in the case already given if $\mathrm{OC}, \mathrm{O} \mathrm{B}, \mathrm{O} \mathrm{A}$, or more briefly $c, b, a$, are the lengths of the axes* (strictly speaking semi-axes) for a given species, then the position of the first plane is expressed by $1 c: 1 b: 1 a$; that of the second by $2 c: 1 b: 1 a$ (if $\mathrm{OD}=2 \mathrm{OC}$ ), and still another plane might be $2 c: 2 b: 1 a$, and so on. Consequently the general position of any plane may be expressed by $m c: n \bar{b}: r a, \dagger$ or more simply $m c: n b: a$, as every plane is for simplicity supposed to meet one of the axes at the unit distance. In the first case mentioned above, $m=1$ and $n=1$; but in general $m$ and $n$ may vary in value from zero to infinity. The law of simple mathematical ratio, however, requires that $m$ and $n$, which express the ratios in the lengths of the axes, should be invariably rational numbers, and in general they are either whole numbers or simple fractions.

This principle may be stated as follows :
The position of the planes in a given crystal is related in some simple ratio to the relative lengths of the axes.

[^0]This subject will become clear in the subsequent study of the different crystalline forms; in passing, however, reference may be made to f. 32 (zireon) as a single example. The planes lettered 1 and 3 have respectively the positions, $1 c: 1 b: 1 a$, and $3 c: 1 b: 1 a$, and in the second case the vertical axis has exactly three times the longth of that of the former; any such multiples as 2.93 or 3.07 are crystallographically impossible. It is this principle which makes crystallography an exact mathematical science. Some apparent exceptions, such as occasionally oceur, do not at
 all set aside this rule.

The expression $n c: n b: a$ is called the symbol of a plane, as it expresses its exact mathematical position, and the valnes of $m$ and $n$ are called its parameters. If a plane intersects two of the axes, but not the third, it is parallel to it, and mathematically it is said to cut it at infinity ( $\infty$ ) ; hence the general expression for a plane parallel to the vertical axis $c$ (as in f. 33) will be $\infty c: n b: a$, or $\infty c: b: n a$, according as $a$ or $b$ is taken as the unit; for a plane parallel to the lateral axis $b$ (as in f .34 ), it will be $m c: \infty b: a$; if parallel to the lateral axis $a$ (as in f. 35), mc:b: $\infty a$.

If a plane is parallel to two axes, $b$ and $a$, that is, intercepts these axes at

an infinite distance, its position is expressed by $c: \infty b: \infty a$, as is illus. trated by f. 36 ; again, its position is expressed by $\infty c: b: \infty a$, if parallel to $c$ and $a$; and by $\infty c: \infty b: a$, if parallel to $c, b$. These may also be written $0 c: b: a$, etc.

The following important principle should be kept in mind. The relative not the absolute position of any plane has to be regarded, and hence all planes parallel to each other are crystallographically identical. A plane on the angle of the cube is the same, if the matual inclinations remain unchanged, whether large or small, for, though the actual distances cut off on the axes may differ in each case, the ratios of these axes are identical. Again, in f. 37, the three planes, $4 c: 4 b: 2 a$, and $2 c: 2 b: a$. and $c:$ $b: \frac{1}{2} a$ are identical, for the ratios of the three axes are the same throughout, the planes being of course parallel. Similarly the symbol $1 c: \frac{1}{8} b: \frac{1}{8} a$ may be writter $3 c: b: a$
and $c: \infty b: \infty a$ is the same as $0 c: b: a$. It will be seen that this prin. ciple makes it right to regard every plane as meeting one of the axes at the unit distance from the centre, which, as before stated, reduces the general expression of any plane $m c: n b: r a$ to the simpler form $m c: n b: a$, or $m c: b: n a$.

The principle, which has just been stated, also makes it evident that when the axes are all equal, they are not necessarily considered in naming the position of any plane; when the lateral axes alone are equal, a certain length of the vertical axis must be assumed for each species ; and when all the axes are unequal, certain lengths for two of the axes, expressed in - terms of the third axis, must in every case be adopted.

Hence the fundamental form of any species may be regarded as that octahedron whose axes correspond in relative lengths with the axes $c, b, a$ adopted for the species. The faces of this octahedron intersect the axes at distances from the centre equal to $n c, n b, n a$ (or $c: b: a$ ) respectively, and, since the ratio of the coefficients which expresses the position of these planes is $1: 1: 1$, this form is also called the unit octahedron. But the form is not necessarily fundamental ; for it is frequently more or less arbitrarily assumed, and the structure or genesis of the crystals of a species may point to other forms, having very different axial relations, as will appear from facts stated beyond.

[^1]
## 2. Law of Symmetry.

The symmetry of crystals is based upon the law that either :

1. All parts of a crystal similar in position with reference to the axes are similar in planes or modification, or

- II. Each half of the similar parts of a crystal, alternate or syminetri. cal in position or relation to the nther half, may be alone similar in its. planes or modifications.

The forms resulting according to the first method are termed holohedral forms, from öخos, all, čò $\rho a$, face; and those according to the second, hemihedral, from $\eta \mu \iota \sigma \nu \varsigma$, half.

According to the law of full or holohedral symmetry, each sectant in one of the rectangular systems (a) should have the same planes both as to number and kind; and (b) whatever the kinds, in each sectant there should be as many of each kind as are geometrically possible. But in hemihedrism. either (a) planes of a kind occur only in half of the sectants; or else (b) half the full number occur in all the sectants.

In the isometric system, for example, if one solid angle of a cube has upon it a plane equally inclined to the diametral sections, so will each of the other angles (or sectants) (f. 39-42).

If one of the twelve edges of the cube has a plane equally inclined to the enclosing cubic faces (or diametral planes) the others will have the same (f. 43-46).

Again, one of the solid angles of a cube being replaced by six planes, as in f .70 , this law requires that the same six planes should appear on all the other solid angles.

But under the law of hemihedrism these planes may occur on half the solid angles of the cube, and not on the other half, as in f. 87, or half the full number of planes may occur on all the angles, as in f. 101. This subject is further elucidated in the discussion of the hemihedral forms belonging to each system of crystallization.

Heminedrism is of varions kinds :

1. Holomorphic, in which the occuring planes pertain equally to both the upper and lower (or opposite) ranges of sectants, as in all ordinary hemihedral forms.
2. Hemimorphic, in which the planes pertain to either the upper or the lower range, and not to both, and hence the planes are only half enongh of the kind to enclose a space, whence the term hemimorphic, from $\tilde{\eta}_{\mu} \boldsymbol{\sigma} \sigma v$. half, and $\mu$ óp $\phi \eta$, form.

The holomorphic forms may be either:
A. Hemiholohedral, HALF the sectants having the FULL number of planes, or
B. Holohemihedral, all the sectants having nalf the whole number of plan ss.

Again, as to the relative positions of the sectants containing the planes, the forms may be :
a. Vertically-direct, in which the sectants of the upper and of the lower ranges are alternate, but the upper not alternate with reference to the lower,
and, accordingly, each plane above is in the same vertical zone with a like plane below ; as in forms described on pp. 34, 35.
b. Vertically-alternate, in which the sectants of the upper and lower ranges are alternate, and also the upper are alternate with reference to the lower, and, accordingly, each plane above is not in the same vertical zone with a like plane below; as in the tetrahedron (f. 9), rhombohedron (f. 16), and gyroidal forms (f. 182).
c. Vertically-oblique, in which the sectants of the upper and lower ranges are adjacent, but the upper are situated diagonally with reference to the lower, being on the opposite side of a transverse diametral or diagonal plane; as in hemihedrons of monoclinic habit under the orthorhombic system (p. 45).

Tetartohedrism.-Mathematically the rhombohedron is a hemihedron under the hexagonal system, consequently the forms that are hemihedral to the rhombohedron are tetartohedrons, or quarter-forms. See p. 39 .

Tetartohedral forms, or those with one-fourth of the normal number of planes, have also been observed in the Isometric system. The term merohedrism, from $\mu$ épos, part, and éठ $\rho \bar{a}$, face, has been used in place of hemihedrism, to include both this and tetartohedrism.

## I.-ISOMETRIC SYSTEM.

## A. Holohedral Forms.

In the Isometric sysitem the axes are equal, so that either one may be the vertical axis, and each may be called $a$. It has already been shown that the general expression for any plane meeting the axes $c, b, a$ is $m c: n b: a$; and in this system it|will be ma:na:a, or, since the axes are equal, simply $m: n: 1$. Now it has been shown also that according as a plane intersects the several axes at different points, or is parallel to one or more of them, this fact is indicated by the values given for $m$ and $n$ in each case (p.11). Hence expressions for all the forms geometrically possible in this system will be obtained if to $m$ and $n$, in the general expression $m a: n a: a$, successive values are given. These values may be in this system, 0,1 , a number greater than 1 , or $\infty$. In this way are derived:-

| 1. $m: n: 1$ | n] | en $m$ and $n$ h than unity. |
| :---: | :---: | :---: |
| 2. $m: m: 1$ |  | when $m>1, n=m$ 。 |
| 3. $m: 1: 1$ | [ m ] | when $m>1, n=1$. |
| 4. $1: 1: 1$ | [1] | when $m$ and $n$ |
| 5. $\infty: n: 1$ | [ $i$ - $n$ ] | hen $m=\infty, n>1$. |
| 6. $\infty: 1: 1$ | [i] | hen $m=\infty, n=1$. |
| 7. $\infty: \infty: 1$ | [H] | en |

In lettering the planes of the several forms only the essential part of the symbol is used: the oube is $H$ (hexahedron); the octahedron $1(=1: 1: 1)$; the dodecahedron $\delta(\infty: 1: 1)$, ( $i$ stands for infinity); $m$ is used for the planes $m: 1: 1 ; m \cdot m$ fox $m: m: 1 ; i-n$ for os $: n: 1$.
$m-n$ for $m: n: 1$. These symbols are the same as those of Naumann, except that he wrote $\infty$ instead of $i$ for infinity, and introduced also the letter $O$ (octahedron) as the sign of the system; $\infty 0 \infty$ of his system $=H ; 0=1 ; \infty 0=i ; m 0=m ; m 0 m=n \cdot m, \infty 0 n=i-n$. and $m O n=m-n$.

Each of these expressions, appearing at first sight possibly a little obscure, may be translated into simple language.

Cube.-The cube with the symbol $\infty: \infty: 1$, is composed of planes each one of which is parallel to two of the axes, and meets the third at its unit point (see f. 36). It is evident that there are six such planes, one at each extremity of the three axes, and the figure or crystal which is enclosed by these six planes has already been described (p. 5) as the cube (f. 38).

Octahedron.-The symbol 1:1:1 comprises all those planes which meet the three axes at the same distance, that is, cut off the unit length of each. It is evident that there must be eight such planes, one in each octant, and they together form the regular octahedron (f.42), which has already been desuribed, p. 4.

Dodecahedron.-The symbol $\infty: 1: 1$ includes those planes which intercept two of the axes at the same unit distance, and are parallel to the third. There can be twelve planes answering to these conditions, and they form together the dodecahedron (f. 45, see also p. 6).

These three forms, the cube, octahedron, and dodecahedron, are those most commonly occurring in this system, and it is important that their relation should be thoronghly understood. The transitions between these forms, as they modify one another, are exhibited in the following figures:


Figs. 35 and 42 represent the cube and octahedron, and $39,40,41$, the intermediate forms. Slicing off from the eight angles of a cube piece after 1 iece, such that the planes made are equally inclined to $H$, or the cubic faces, the eube is finally converted into the regular octahedron; and the last disappearing point of each face of the cube is the apex of each solid angle uf the octahedron. The axes of the former, therefore, of necessity connect the-apices of the solid angles of the latter.

The form in f .40 is called a cubo-octahedron. ' $I \wedge \wedge 1=125^{\circ} 15^{\prime} 52^{\prime}$ ".
If the twelve edges of the cube are truncated (for all will he truncated if to is) it affords the form in $f .43$; then that of f. 44: then the dodecahe-
dron, f. 45 ; the axes of the cube becoming, in the transition, the axes son necting the tetrahedral solid angles of the dodecahedron ; $H \wedge i=135^{\circ}$. If the twelve edges of the octahedron (f.42) are truncated, the form in f. 47 results ; and by continuing the replacement, finally the dodecahedron again is formed (f. 45 ). $1 \wedge i=144^{\circ} 44^{\prime} 8^{\prime \prime}$. The last point of the face of the octahedron, as it disappears, is the apex of the trihedral solid angle of the dodecahedron.

These forms are thus mutually derivable. The process may be reversed, the cube being derivable from the dodecahedron by the truncation of the tetrahedral solid angles of the latter (compare in succession f. 45, 44, 43, $38)$; and the octahedron by the truncation of the trihedral solid angles (compare f. $45,47,42$ ). These remarks are important as showing the relations between these forms, though it is of course not intended to be understood that they are in any sense derived from each other in this manner in nature.

The three axes (or cubic axes) connect the centres of opposite faces in the cube ; the apices of opposite solid angles in the octahedron; the apices of opposite tetrahedral solid angles in the dodecahedron.

The eight trigonal or octahedral interaxes connect the centres of opposite faces in the octakedron; the apices of opposite solid angles in the cube; the apices of opposite trihedral solid angles in the dodecahedron.

The twelve rhombic or dodecahedral interaxes connect the centres of opposite faces in the dodecahedron; the centres of opposite edges both in the cube and the octahedron.

In a vertical section, containing each of these kinds of axes, the octahe dral interaxis intersects one of the three cubic axes at the angles $54^{\circ} 44^{\prime} \delta$ and $125^{\circ} 15^{\prime} 52^{\prime \prime}$, and one of the dodecahedral interaxes, at the angles $35^{\circ} 15^{\prime} 52^{\prime \prime}$ and $144^{\circ} 44^{\prime} 8^{\prime \prime}$.

There remain four other holohedral forms belonging to the system as contained in the list on page 14.

Trisoctahedrons. - The symbol $m: 1: 1$ is of that solid each of whose planes meets two of the axes at the unit distance, and the third axis at some distance which is a multiple of this mit length. It will be evident, as in f. 48, that there are three such planes in each of the eight sectants, and hence the total number of planes by which the solid is bounded is twenty-four. The resulting solid is called a trigonal trisoctahedron, and one, having
 $m=\frac{3}{2}$, is shown in f. 49 .

[^2]noting the points where the different planes intersect. Further remarks on the drawing of crystals will be found in the Appendix.

The syinbol $m: m: 1$ belongs to all the planes which meet one axis at the unit distance, and the others at equal distances which are multiples of the former. As seen in the preceding case, there will be three such planes in each of the eight sectants, and the total number consequently will be twenty-four. The solid is seen in f .50 , and is called a tetragonal trisoctaliedron, or a trapezohedron.

Both these forms are called trisoctahedrons, from $\tau \rho i s$, three times, and octahedron, becanse in each a three-sided pyramid occupies the position of the planes of the regular octahedron. They are closely related to each other; starting with the form $m: 1: 1$, if $m$ is diminished till it equals mity, then the symbol becomes $1: 1: 1$, that is, it has passed into the octahedron. If $m$ becomes less than unity, the symbol may be, for example, $\frac{1}{2}: 1: 1$, which is identical, as has been explained ( p .11 ) with $1: 2: 2(2-2)$, and this is the symbol of the second trisoctahedron. This explains why, in the first list comprising all the possible forms, $m$ was in no case made less than mity.

Trigonal-trisoctakedron.-In this form the solid angles are of two kinds: the trigonal or octahedral, and the octagonal or cubic. The edges are thirty-six in number, twenty-four of one kind, forming the octahedral or trihedral solid angles, and twelve edges meeting at the extremities of the cubic axes. Each of the twenty-four planes is an isosceles triangle.


In combination with the cube, the form 2 appears as a replacement of each of the solid angles by three planes equally inclined on the edges; this is scen in f. 52. With the octahedron, it appears as a bevelment of its twolve edges, as shown in f. 53. It.also replaces the eight trigonal solid angles of a dodecahedron by three planes inclining on the faces. The more commonly oceurring examples of this form are $2(=2: 1: 1)$, also $\frac{3}{2}\left(=\frac{3}{2}\right.$ $: 1: 1)$, and $3(3: 1: 1)$.

The Tetragonal-trisoctahedron or trapezohedron, has three kinds of solid angles: six cubic, whose truncations are cubic faces (f. 56) ; eight octahedral, whose truncations are octahedral faces (f. 56) ; twelve dodecahedral, truncated hy the dodecahedral planes (f. 60). It has forty-eight edges; twenty-four of one kind, those of the trihedral or octahedral solid angles, and the remaining twenty-four, also of one kind, meeting in the ewbic solid angles. Each of the twenty-four faces is a quadrilateral.

In combination with the cube it is seen in $f .55,56$, appearing as a-re placeinent of each of the solid angles by three planes equally inclined on
the faces of the cube. Figs. 56,57,58,59, 60, 62, also show it in cons bination with the octahedron and dodecahedron. The most commonly occurring of this series is 2-2 ( $=2: 2: 1$ ), f. 54 ; as seen in f .59 , it truncates the twenty-four edges of the dodecahedron. On the other hand the form

${ }^{\frac{8}{2}}-\frac{3}{2}$ would replace the trihedral solid angles by planes inclined on the edges, while 3-3 replaces (f. 62), the tetrahedral solid angles of the dodecahedron, by planes also inclined on the edges.

Tetrahexahedron.-The symbol $\infty: n: 1(i-n)$ belongs to all the planes which are parallel to one axis, meet a second at the unit distance, and the third at some multiple of that. There are twenty-four planes which satisfy these conditions, and they form the tetrahexahedron; f. 64, 65, represent two varieties of tetrahexahedrons. It will be seen that the planes are so arranged that a square pyramid corresponds to each of the six faces of the cube; and hence the name from тєтракıs, four times, $\approx \xi$, six, and é $\delta \rho a$, fuce, it being a $4 \times 6$-faced solid. The tetrahexahedron has six tetrahedral solid angles and eight hexahedral or octahedral solid angles. There are twenty-forr edges of one kind forming the former solid angles, and twelve edges occupying the position of the cubic edges. Each of the twenty-four faces is an isosceles triangle. In combination with the cube it produces a bevelment of its twelve edges, as represented in f .64 .


The tetrahexahedron, in $f .65$, lettered $i-2$, has the symbol $\infty: 2: 1 ;$ and that of $f$. 66 , lettered $i-3, \infty: 3: 1$. Some of the other occurring kinds are those with the ratios, $2: 3,3: 4,4: 5$, etc., etc.

The relation of the tetrahexahedron to the octahedron is shown in f. 67 Py comparing this figure with f .42 , it is seen that the planes $i-2$ rel lace
the solid angles of the octahedron by planes inclined on its edges. Its rela. tion to the dodecahedron is presented in f .68 , which is a dodecahedron (planes $i$ being the dodecahedral planes, see f . 45) with the tetrahedral solid angles replaced by four planes inclined each on an $i$.

The tetrahexahedron is called a fluoroid, by Haidinger, the form being common in fluorite. It is the Tetrakishexahedron (or Pyramidenwürfel) of Naumann.

In accordance with considerations already presented it is evident that $n$, in the symbol $i-n$, may always be written as a whole number, for the symbol $\infty: \frac{1}{2}: 1$ is identical with $\infty: 1: 2$. Moreover it is seen that when $n$ is $\infty$, the form passes into the cube ( $\infty: \infty: 1$ ), and as $n$ diminishes and becomes unity, it passes into the dodecahedron ( $\infty: 1: 1$ ).

Hexoctahedron.-The general form $m: n$ includes the largest number of similar planes geometrically possible in this system. This symbol requires six planes in each octant, as will be seen by a method of construction similar to that in f. 48 , and consequently the whole solid has forty-eight planes. It is hence called a hexakisoctahedron ( $\kappa \xi$ 觖ьs, six times, öкт $\omega$, eight, and $\tilde{\varepsilon} \delta \rho a$, face, i.e., a $6 \times 8$-faced solid) or hexoctahedron. The form is shown in f . 69 , where it will be seen that there are three different kinds of edges, and three kinds of solid angles; each of the fortyeight planes is a scalene triangle.

When modifying the cube it appears as six planes replacing each of the solid angles, f. 70. It replaces the eight angles of the octahedron, and the

form 3-3 bevels the twenty-four edges of the dodecahedron (f. 71). Other hexoctahedrons, differing in their angles, may replace the six acute solid angles of the dodecahedron by eight planes, or the eight obtuse by six planes.

The hexoctahedron of $\mathrm{f} .69,70,71$ is that whose planes have the axia ratio $: \frac{3}{8}: 1$. Others have the ratio $4: 2: 1,2: \frac{4}{3}: 1(=6: 4: 3), 5: \frac{5}{3}: 1$ $(=15: 5: 3), 7: \frac{7}{3}: 1(=21: 7: 3)$, etc.


Amalgam.

73


Magnetite.

The preceding figures show dodecahedrons variously modinied. In f. $72, I$, or $i$, are faces of the dodecahedron; $H$ of the cube; 1 of the octahedron; $i-3$ of a tetrahexahedron (f. 66); 2-2 of the trapezohedron of f. 54 $59 ; 3-\frac{3}{2}$ of the hexoctahedron of $f .69,70$. In $f .73, i, O$, and 1 are as in f. 72 ; $3-3$ is the trapezohedron of $f .61,62$; and $5-\frac{5}{3}$ (either side of $3-3$ ) a hexoctahedron.

The hexoctahedron is called the adamantoid by Haidinger, in allusion to its being a common form of crystals of diamond. It is the hexakisoctahedron of Naumann.

## B. Hemihedral Forms.

Of the kinds of hemihedral forms mentioned on page 13, the hemiholohedral, in which only half of the sectants are represented in the form, produces what are called inclined hemihedrons; and the holohemilhedial, in which all the sectants are represented by half the full number of planes, parallel hemihedrons. In the former the sectants to which the occurring planes belong are diagonally opposite to those withont the same planes; and hence no plane has another opposite and parallel to it; on the contrary, opposite planes are oblique to one another, and hence the name of inclined hemihedrons applied to them. They are also called tetrahedral forms, the tetrahedron being the simplest form of the number, and its habit characteristic of them all; while the latter are called pyritohedral, becanse observed in the species pyrite. The complete symbols of the inclined hemihedrons are written in the general form $\frac{1}{2}(m: n: 1)$, of the parallel hemihedrons in the form $\frac{1}{3}[m: n: 1]$; also written $\kappa(m: n: 1)$ and $\pi(m: n: 1)$ respectively:
a. Inclined or Tetrahedral Hemihedrons. 1. Tetrahedron, or Hemioctakedron. $-\frac{1}{2}(1: 1: 1)$.

As has been shown, the form $1(1: 1: 1)$ embraces eight planes, and when holohedrally developed it produces the octahedron; in accordance, however, with the law of hemihedrism, half of the eight possible planes may

occur in alternate octants; thus in two opposite sectants above, and the two diagonally opposite below, as shown by the shaded planes in f. 74. If
these four shaded planes are suppressed, while the other four of the octahedron are extended, the resulting form is the regular tetrahedron, f. 76. The relation of the octahedron and tetrahedron may be better understood from f. 75. If, as just remarked, the planes shaded in f. 74 are suppressed, while the others are extended, it will be seen in f .75 that the two latter pairs intersect in edges parallel respectively to the basal edges of the octahedron, and the complete tetrahedron is the result. The axes, it is important to observe, connect the middle points of the opposite edges.

Further than this, since either set of four planes may go to form the solid, two tetrahedrons are evidently possible, and they may be distinguished by calling the first, f. 76, positive, and the second negative, f. 76a: These terms are of course only relative. The plus and the minus tetrahedrons may oceur in combination, as in f .79 ; and thongh there are here present the eight planes which in holohedral forms make the octahedron, and though they should happen to be equally developed so as to give the same shape, the crystal would still be pronounced tetrahedral, since the planes 1 and -1 are physically different. An example of this occurs in crystals of boracite, where the planes of one tetrahedron are polished while those of the other are without lustre.

The plane angles of the tetrahedron are $60^{\circ}$, and the interfacial angles $70^{\circ} 31^{\prime} 44^{\prime \prime}$.

The combinations of the cube and tetrahedron are shown in f .77 and 78, and the dodecahedron and tetrahedron in f. 80. As the octahedron results geometrically from slicing off successively the solid angles of the cube, by planes of equal inclination on the cubic faces, so also the tetrahedron may be made mechanically by slicing off similarly half these solid angles.


Hemi-trisoctahedrons, $\frac{1}{2}(m: m: 1)$ and $\frac{1}{2}(m: 1: 1)$. In the same manner as with the tetrahedron, the form $m-m$, when hemihedral, may have half its twenty-four planes present, viz., those in the two opposice sectants above and the alternate sectants below. When these twelve planes are extended, the others being suppressed, they form the solid represented in f. 81 ; the symbol properly being $\frac{1}{2}(m-m)$, or here $\frac{1}{2}(2-2)$. The faces, as will be ob served, tre trigonal, and the solid is sometimes called a cuproid. There is the same distinction to be made here between the plus and the minus forms as with the tetrahedrons. Figs. $82,83,84$ show combinations of $+\frac{1}{2}(m-m)$ with the plus tetrahedron, the dodecahedron, and the tetrahexahedron.

Bimilarly the form $m$, when hemihedral, according to the same principle results in the solid, f. 85. It is called the deltohedron by Haidinger; it has trapezoidal faces. In f. $86,+\frac{1}{2}\left(\frac{8}{8}\right)$ is shown in combination with $+\frac{1}{2}(2-2)$. Here also the distinction between the plus and minus forms is to be made in the same manner as that already explained.

Inclined or tetrahedral Hemi-hexoctahedron $\frac{1}{3}(m: n: 1)$. The form $m-n$ when developed according to the law of inclined hemihedrism, that is, when of its forty-eight faces, half are present, viz., all in half the whole


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87


88

number of sectants, produces the solid seen in f. 87 . There is here also $\mathrm{a} /$ plus solid, and a minus solid, corresponding to the + and - tetrahedronl In f. 88 it is in combination with the plus tetrahedron.

If the same method of inclined hemihedrism be applied to the remaining solids of this system, the cube, dodecahedron, and tetrahexahedron, that is, if in each case the parts in two opposite sectants above, and the two diagonally opposite sectants below, be conceived to be extended, the other half being suppressed, it will be seen that the solid reproduces itself; the hemihedral form of the cube is the cube, and so of the others.

The following figures represent some other combinations of these forms.

$$
89
$$



Sphalerite.

89A


Sphalerite.


Tetrahedrite.

In f. 89, the cuproid $3-3$ is combined with the faces $I$ of a dodecaliedron. The form 3.3 resembles closely that of f .81 , but in its combiration with the dodecahedron it does not truncate an edge of the dodecahedron, like 2-2 inf. 83. Fig. 89A contains the same planes combined with the plus tetrahedron, hexagonal planes 1, the minus tetrahedron, triangular planes 1, and the faces of the cube $H$. The presence of the plane $H$ facilitates the comparison of the form with f. $55,56,57$, p. 18 , the plane $3-\mathrm{s}$ having the same position essentially with 2-2. Fig. 90 has as its most prominent planes those of $f$. 81 , but the position given it is relatively to $f .81$ that of the minus hemihedron; and there are also the small planes 2-2 about the angles, which are those of the minus hemihedron. $H$, are planes of the cube; 1 , those of the tetrahedron; $i$, those of the dodecahedron; $i-3$ those of a tetrahexahedron ( $H, i, i-3$ all holohedral) ; and $\frac{3}{2}$ the planes of a deltoh dron similar to f. 85 , and occurring with 2-2 in f .86.
b. Parallel or pyritohedral hemihedrons.-According to the second law of hemihedrism, half the whole number of planes of any form may be present in all the sectants. In the resulting solids each plane has another parallel to it. This method of hemihedrism obviously produces distinct forms only in those cases where there is an even number of planes in each octant.

Pentagonal Dodecahedron, or Hemi-tetrahexahedron, $\frac{1}{2}(\infty: n: 1)$. If of the twenty-four planes of the form $i-n(\infty: n: 1)$, only half are present; viz., one of each pair in the manner indicated by shading in f. 91 , these being extended while the others are suppressed, the solids in f. 92 and f. 93 result. The parallelism of each pair of opposite planes will be seen in these figures. These two possible forms, seen in the figures, are distinguished by calling one plus (arbitrarily), $+\frac{1}{2}[i-2]$, and the other minus, $-\frac{1}{2}[i-2]$. These solids are yery common in the species pyrite, and are hence called pyritohedrons ; they are also called pentagonal dodecahedrons, in allusion to their pentagonal faces. The regular dodecahedron of geometry belongs to this class, but is an impossible form in nature, since for it $n$ must have an irrational value, viz., $\frac{1+\sqrt{5}}{2}$, see p. 10 .

In combination with the cube the form $+\frac{1}{2}[i-2]$ is seen in $f .94$ and f. 95 , and in f. 96,97 , with the octahedron, and in f. 98 , with the cube and octahedron.


Parallel hemi-hexoctahedron, $\frac{1}{2}[m: n: 1]$. When of the forty-eight planes of the form $m-n$, only half are present, viz., the three $\triangleleft$ alternate

planes in each octant as indicated by the shading in f. 99 , the solid in f. 100 results. This solid is called a diploid by Haidinger. It is also called
a dyakis-dodecahedron. Inf. 101 it is shown in combination with the cube. and inf. 102 with the octahedron.

Figs. 103, 104, 105, of the species pyrite, represent various combinations of parallel hemihedrons with the cubic and other faces. In f. 103 there are planes of two hemi-tetrahexahedrons (pentagonal dodecahedrons) $i-2, i-\frac{3}{2}$; and of two diploids $4-2,3-\frac{3}{2}$, along with planes of the octahedron, 1, and of the trapezohedron 2-2. In f. 104 the dominant form is the dodecaliedron, $I$; it has the faces of the cube, $H$; of the octahedron, 1 ; of the

trapezohedron, 2-2; and of the parallel hemihedrons, $i-2$ and 4-2. Fing. 105 represents a map of one angle of cube, showing at centre the octahedral face 1 , and around it the faces of the cube $H$, of the trapezohedron 2-2, the trigonal trisoctahedron 2, and the parallel hemihedrons, $i-2,2-\frac{4}{3}$, $3-\frac{3}{2}$. The axial ratio for $2-\frac{4}{3}$ is $2: \frac{4}{3}: 1$ (or $6: 4: 2$ ), and for $3-\frac{1}{2}, 3: \frac{3}{2}: 1$ (or $6: 3: 2$ ).

Prominent distinctive characters.-The student, in order to facilitate his study of Isometric forms in nature, shonld be thoroughly familiar with the following points, from the study of models or natural crystals; (1) The isometric character of the symmetry, the planes being alike in grouping in the direction of the three axes. (2) The forms of the faces and solid angles of the octahedron, the dodecahedron, the trapezohedron 2-2, the pentagonal dodecahedron $i-2$. (3) The fact that the following are common angles in the system- $135^{\circ}(=\mathrm{H} \wedge i) ; 109^{\circ} 28^{\prime}$ (angle of octahedron), $70^{\circ} 32^{\prime}$ (angle in octahedron and tetrahedron); $120^{\circ}$ (angle of dodecahedron); $125^{\circ}$ $16^{\prime}(=\mathrm{H} \wedge 1) ; 144^{\circ} 44^{\prime}(=\mathrm{H} \wedge 2-2=1 \wedge i) ; 153^{\circ} \simeq 6^{\prime}(=\mathrm{H} \wedge i-2) ; 161^{\circ} 34^{\prime}(=\mathrm{H}$ ^i-3). A list of the angles belonging to the varions forms of this system is given on p. 67. (4) Cleavage may be cubic, octahedral, or dodecahedral ; and sometimes two of these kinds, and occasionally the three, occur in the same species, but always with great difference of facility between them. Galenite is an example of easy cubic cleavage; fluorite of easy octahedral; sphalerite (blende) of casy dodecahedral.

Dü̈ites of symmetry.-The seven kinds of solids described on pp. 15 to 19, include all the holohedral forms possible in this system, as is evident from their geometrical development. In them exists the highest degree of sym metry possible in any geometrical solids.

In the cube, as has already been stated, all planes, solid angles, and edges are equal and similar. The three diametral planes, passing each through two of the axes. are the chief planes of symmetry, every part of the crystal
on one side of the plane having its equal and symmetrical part on the opposite side. Further than this, each of the six planes passing through the diagonal edges of the cube, and consequently parallel to the dodecahedral planes, are also planes of symmetry. There are hence in this system nine planes of symmetry.

## II.-TETRAGONAL SYSTEM.

In the Tetragonal System, there are three rectangular axes; but while the two lateral axes are equal, the remaining vertical axis is either longer or shorter than they are; there are consequently to be considered the lateral axes (a) and the vertical axis (c).

The gencral geometrical expression for the planes of crystals becomes for this system $m c: n a: a$, and, if this be developed in the same way as the corresponding expression in the Isometric system, all the forms* geometrically possible are derived.

| 1. | $c: n a: a \quad$ [ | [m-n] | when $m>1, n>1$. |
| :---: | :---: | :---: | :---: |
|  | $\{c: a: a$ | [1] | when $m=1, n=1$. |
|  | $\{m e: a: a$ |  | when $m \gtrless 1, n=1$. |
|  | $\int c: \infty a: a$ | [1-i] | when $n=1, n=\infty$. |
|  | $\left\{\begin{array}{l}m c: \infty a: a\end{array}\right.$ | [ $m-i$ ] | when $m \gtrless 1, n=\infty$. |
| 4. | $\infty c: n a: a$ | [i-n] | when $m=\infty, n>1$. |
| 5. | $\infty c: a: a$ | 1 | when $m=\infty, n=1$. |
| 6. | $\infty c: \infty a: a$ | [i-i] | when $m=\infty$ |
|  | $\{(c: \infty a: \infty a)$ | [O] | when $m=0, n=1$. |

In lettering the planes the abridged symbols are used; here, as before, $i=\infty$, and the unit Lerin is omitted as unnecessary, mc: $\infty a: a=m-i$, etc. These are the same as the symbols oi Naumann, except that he wrote $\infty$, and added $P$ as the sign of the systems which are not isometric ; $0 P=0 ; \infty P \infty=i-i ; \infty P=I ; \infty P n=i-n ; m P \infty \infty=m-i ; m \mathrm{P}=m ; P=1$; and $m P^{P} n=m-n$.

## A. Holohedral Forms.

Basal plane.-There are two similar planes corresponding to the symbol $c: \infty a: \infty a$ (or $0 c: a: a$ ), parallel to both the lateral axes; each is called the basal plane. They do not inclose a space, and consequently they can occur onlv in combination with other planes.

Prisms.-The planes having the symbol $\infty c: \infty a: a$ are parallel to the vertical and one of the lateral axes. There are four such planes, one at each extremity of the two lateral axes, and, in combination with the plane $O$, they form the square prism, which has been called the diametral prism, scen in f. 106.

For the symbol $\infty c: a: a$, the planes are parallel to the vertical axis,

[^3]and meet the others at equal distances. There are, as in the preceding case, four such planes. They form, in combination with the plane $O$, that square prism which is seen in f. 107, and may be called the unit prisin. Both the prisms $i-i$ and $I$ are alike in their degree of symmetry. Each has four similar vertical edges, and eight similar basal edges unlike the vertical. There are also in each case eight similar solid angles.


The form $i-n(\infty c: n a: a)$ is another prism, but in this each plane meets one of the lateral axes at the unit distance, and the other at some multiple of its unit distance. As is evident in the accompanying horizontal section (f. 113), this general symbol requires eight similar planes, two in each quadrant, and the complete form is shown in f. 109. The sixteen basal edges are all similar; the vertical edges are of two kinds, four axial $X$, and four diagonal $Y$ (f.109). The regular octagonal prism with eight similar vertical edges, each angle being $135^{\circ}$, is crystallographically impossible.

111


112


113


The planes $I$ truncate the edges of the diametral prism $i-i$, as in f .108. Similarly the planes $i-i$ truncate the vertical edges of 1 . The prism $i-n$ bevels the edges of $i \cdot i$, as in $f .110$, where $i-n=i-2$.

The relation of the two square prisms, $i-i$ and $I$, may be further illustrated by the figs. 111 and 112. In f. 112 the sections of the two prisms are shown with the dotted lines for the axes, and in f . 111 there are the two forms complete, the one $(I)$ within the other $(i-i)$. The unit prism $I$ is sometimes called the prism of the first series, and the prism $i-i$ that of the second series.

Octahedrons or Pyramids.-The forms $m-i$ and $m$ both give rise to square octahedrons, corresponding to the two kinds of square prisms. In $m-i$ the planes are parallel to one lateral axis and meet the vertical axis at variable distances, multiples (denoted by $m$ ) of the unit length. The total number of such planes, for a given value of $m$, is obvious! $y$ eight, and
the form is shown in f. 114 and 115. These planes replace the basal edges of the form shown in f. 106, and $m$ varies in value from 0 to $\infty$ When $m=0$ the four planes above and below coincide with the two basal


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117

planes; as $m$ increases, there arises a series, or zone, of planes, with mutually parallel intersections (f.116); and when $m=\infty$, the octahedral planes $m-i$ coincide with the planes $i-i$. The value of $m$ in a particular species depends upon the unit value assumed for the vertical axis $c$.

The same form replaces the vertical angles of the prism $I$, as in f .117 .


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The octahedrons of the $m$ series meet both of the lateral axes at equal distances and the vertical axis at variable distances. . It is clear that the whole number of planes for this form, when the value of $m$ is given, is also eight, one in each octant. When $m=1$ the solid in f .118 is obtained, which is sometimes called the unit octahedron. As $m$ decreases, the octahedrons become more and more obtuse, till $m=0$, when the eight planes coincide with the two basal planes. As $m$ increases from unity, on the other hand, the octahedrons or pyramids become more and more acute, and when $m=\infty$ they coincide with the prism $I$; this series forms another zone of planes. These octahedrons replace the basal edges in the form f. 107, as seen in f. 119, and as the octahedron is more and more developed it passes to f .120 , and finally to f .118.


The same form replaces the solid angles of the form f. 1.06, as seen in f. 121, and this too gradually passes into f. 122 and f. 114.

The relation of the octahedrons 1 and $1-i$ ( $m$ and $m-i$ ) is the same as that of the prisms $I$ and $i-i$ (compare f.112). Similarly, too, they are often called octahedrons (or pyramids) of the first $(m)$ and second ( $m$ - $i$ ) series.

As will be scen in f. 123, 1-i truncates the pyramidal edges of the octaheds $n 1$, and, conversely, the edges of the octahedron $2-i$ are truncated by the octahedron 1 (f. 124).

Octagonal pyramids.-The form $m-n$ ( $m c$ : $m a: a)$ in this system has, as in the preceding system, the highest number of similar planes which are geometrically possible; in this case the number is obviously sixteen, two in each of the eight sectants, as in f. 125 , where $m=1, n=2$. These sixteen similar planes together form the octagonal pyramid (strictly double pyramid) or zirconoid, f. 126. It has two kinds of terminal edges, the axial $X$ and the diagonal $Y$; the basal edges are all similar. It is seen ( $n-n=1-2$ ) in f. 127 in combination with the diametral prism, and in f. 128 with 1, where it bevels the vertical edges.



## B. Hemihedral Forms.

Among hemihedral forms there are two divisions, as in the isometric aybtem:

1. Hemiholohedral, having the full number of planes in half the sectants (a) Vertically-alternate, or sphenoidal forms. The planes occur in two sectants situated in a diagonal line at one extremity, and two in the tranaverse diagonal at the other.

With octahedral planes $\frac{1}{2}(m c: a: a)$ the solid is a tetrahedron (f. 130, 131) called a sphenoid, having the same relation to the square prism of

f. 106 that the regular tetrahedron has to the cube. Fig. 130 is the positive sphenoid or +1 , and 131 the negative, or -1 . The form $\frac{1}{\frac{1}{2}(m c: \infty a: a)}$ is similar. Fig. 132 represents the sphenoid in combination with the prism $i-i$.

If the planes of each sectant are the two of the octagonal pyranid $\frac{1}{2}(m c: n a: a)$ (f.126), the form is a diploid (f. 133). It is in combination with the octahedron $1-i$ in $f .134$.
(b) Vertically-direct, or the planes occuring in two opposite sectants above, and in two on the same diagonal below. The result is a horizontal prism, or forms resembling those of the orthorhombic system. Characterizes crystals of edingtonite.
(c) Vertically-oblique. Planes occurring in two adjacent octants above, and in two diagonally opposite below, producing monoclinic forms, as in a hydrous aminonium sulphate.
2. Holohemihedral, all the sectants havinghalf the full number of planes. As the largest number of planes of a kind is two, half the full number is in all cases one. Hemihedrism may occur in the forms $m-n$ (f. 126, 127), or zirconoids, and in the forms $i-n$ (f. 109), or the octagonal prism.

The following are the kinds :
(a) Vertically-direct. The occurring plane of the sectants, the right one in the upper series, and that in the same vertical zone below, as indicated by the shading in f. 135 ; or else the left one above, and that in the same vertical zone below, f. 136 .

(b) Vertically-alternate. The occurring plane the right above, and that in the alternate zone below, as indicated in f .137 ; or else the luft above, and that in the alternate zone below, f. 138.

As the right of the two planes above is in the same vertical zone with the left of the two below (supposing the lower end made the upper), the two kinds of the first division will be the $r l m-n$; and the $l r m-n$ (in f. 136 on the angles of the prism $i-i$; and the two of the second division the or $m-n$ and the $l l m-n$ (in f. 138 , on the angles of the prism $i-2$ ).

The completed form for the first methods has parallel faces, and is like the ordinary square octahedron in shape, because the upper and lower planes belong to the same vertical zone. But in the second it is gyroidal; the upper pyramid has its faces in the same vertical line with an edge of the lower, as represented in f. 139, the form ll m-n.

The first of these methods occurs in octagonal prisms, producing a square prism, either $r i-n$, or $l i-n$.

Fig. 140 represents a combination of the octahedron $1-i$ with the unit-octahedron 1, and two hemihedral forms, one of them $\operatorname{lr}$ 1-2, the other $r l$ 3-3. The plane 1 shows the position of the octant ; $3-3$ is to the right of 1, and 1-2 to the left. In f. 141, which is a top view of a crystal of wernerite, there occurs $l 3-3$ large, along with $r$ 3-3 small, indicating hemihedrism, and, judging from that of the allied species sarcolite, it is of the square octahedral kind, $r l$ 3-3 and lr 3-3. Fig. 142 contains the hemihedral prism $l i-\frac{4}{3}$, com-


Scheelite. bined with the unit-octahedron 1 , and the basal plane 0 .

Variable elements in this system.-In the tetragonal system two elements are variable, and in any given case must be decided before the relations of the forms can be definitely expressed.
(a) The position of the lateral axes.-These axes are equal, but there are two possible positions for them, for in a given square octahedron they may be cither diagonal or diametral; in other words, given an octahedron, as in f. 115,116 , the prismatic planes may be made diametral ( $i-i$ ), and the octahedron so belong to the $m-i$ series, or the prismatic planes may be made diagonal, that is $I(\infty c: a: a$ ), when the corresponding octahedrons belong to the $m$ series. The ratio of the lateral axes for the two cases is obviously $1: \sqrt{2}$, or $1: 1.4142+$.
(b) The length of the vertical axis.-Among the several occurring octahedrons, one must be assumed as the unit, and the others referred to it. In f. 143 , of zircon, the octahedron 1 is made the unit, and by measuring the basal angle it is found mathematically, as explained later, that the length of the vertical axis is 0.85 times that of the lateral axes. The octahedron 3 has then the symbol $3 c: a: a$ as referred to this unit. If the latter octahedron had been taken as the fundamental form, the length of the vertical axis would have been $3 \times 0.85$ times that of the lateral axes, and the symbol of the first
 plane would have been $\frac{1}{8} c: a: a$. Which form is to be taken as the unit or fundamental, that is, what length of the vertical axis $c$ is to he adopted, depends upon various considerations. In general that form is
assumed as fundarental which is of most common occurrer.ee or to which the cleavage is parallel ; or which best shows the morphological relations of the given species to others related to it in chemical composition, or which gives the simplest symbols for the occurring forms of a species.

Prominent characteristics of ordinary tetragonal forms.-The prominent distinguishing characteristics of tetragonal forms are: (1) A symmótrical arrangement of the planes in fours or eights. (2) The frequent occurrence of a square prism diagonal to a square prism, the one making with the other an angle of $135^{\circ}$. (3) The occurrence of bevelling planes on the latcral edges of the oquare prism. (4) A resemblance of the octahedrons to the regular octahedron, in laving a square base, but a dissimilarity in that the angles over the basal edges do not equal those over the terminal. (5) Cleavage may be either basal, square-prismatic, or octahedral; prismatic cleavage, when existing, is alike in two directions, parallel to the lateral faces of one of the square prisms, and is always dissimilar to the basal cleavage ; the basal, or the lateral, is sometimes indistinct or wanting ; the prismatic may occur parallel to the lateral planes of both square prisms, but when so, that of one will be always unlike in facility that of the other.

Planes of symmetry.-There are five planes of symmetry in the tetragonal system : one principal plane of symmetry normal to the vertical axis, and four others, intersecting in this axis; these four are in two pairs, the planes of each pair normal $\left(90^{\circ}\right)$ to each other, and diagonal $\left(45^{\circ}\right)$ to those of the other.

## III.—HEXAGONAL SYSTEM.

The Hexagonal System includes two grand divisions: 1. The Hexagonal proper, in which (1) symmetry is by sixes, and multiples of six; (2) hemihedral forms are of the kind called vertically-direct; and (3) cleavage and atl physical characters have direct relations to the holohedral hexagonal form.
2. The Rhombonedral, in which (1) symmetry is by threes and multiples of three, rhombohedral forms being hemihedral in mathematical relation to the hexagonal system, and of the kind called vertically-alternate; (2) cleavage, and many other physical characters, usually partake of the hemihedrism.

While the rhombohedron is mathematically a hemihedral form under the hexagonal system, and is properly so treated in a system of mathematical crystallography, it is not so genetically, or in its fundamental relations. Moreover, it has its own hemihedral forms, which, under the broad hexagonal system, are tetartohedral.

The holohedral forms, all of which belong to the Hexagonal division, are here first described; and then the hemihedral forms, which include, besides a few under the hexagonal division, the whole of the Rhombohedral division.

## A. Holohedral Forms : Hexagonal Division.

The general expression for planes of this system is $m c: n a: a: p a$, where there are to be considered the vertical axis, $\dot{c}$, and three equal lateral axes, $a$.

It is evident, however, that the position of any plane is determined by ito intersections with two of the lateral axes, as its direction with the third follows directly from them. (Compare f. 146.) Consequently, in writing the symbol of any plane it is necessary to take into consideration only the vertical axis, and two of the lateral axes adjacent to each other.

The various holohedral forms possible in this system are derived after the analogy of those of the tetragonal systein. The parameters for all the lateral axes are giver: below for sake of comparison. It is to be noted here that $m$ may be either $<1$, or $>1 ; n$ is always $>1$ and $<2$, while $p>2$ and $<\infty$; further than this it is always true that $p=\frac{n}{n-1}$.

$$
\left.\begin{array}{l}
m c: n a: a:(p a) \\
m c:[m-n] \text { when } m>1, n>1 \text { and }<2 . \\
\left\{\begin{array}{ll}
m c: a: a:(2 a) & {[m-2] \text { when } m>1, n=2 .} \\
c: a: a:(\infty a) & {[m] \text { when } m>1, n=1 .}
\end{array}\right][1] \text { when } m=1, n=1 .
\end{array}\right] \begin{array}{ll}
\infty c: n a: a:(p a) & {[i-n] \text { when } m=\infty, n>1 \text { and }<2 .} \\
\infty c: 2 a: a:(2 a) & {[i-2] \text { when } m=\infty, n=2 .} \\
\infty c: a: a:(\infty a) & {[I] \text { when } m=\infty, n=1 .} \\
0 c: a: a:(a) & {[0] \text { when } m=0, n=1 .}
\end{array}
$$

The abridged symbols need no explanation beyond that which has been given on p .25 ; $m P n=m-n ; \infty P n=i-n$, etc.

Basal planes.-The form $O=0 c: a: a$ includes the two basal planes bove and below, parallel to the plane of the lateral axes.

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Prisms.-The form $I=\infty c: a: a$ comprises the six planes parallel to the vertical axis, and meeting the two adjoining lateral axes at equal distances. These six planes with the basal plane form the hexagonal unit prism, f. 144. The form $i-2=\infty c: 2 a: a$ includes the six planes which are parallel to the vertical axis but meet one of the lateral axes at the unit distance, and the other two at double that distance. These plawes with the basal plane form the diametral prism, f. 145 . The relations ot the two prisms $I$ and $i-2$ are shown in f.146. In f. 147, it will be seen that the one prism truncates the vertical edges of the other. The faces of the $i-2$ make an angle of $150^{\circ}$ with the faces of $I$. These two prisms have an intimate connection with each other, and together form a regular twelve-sided prism,-a prism which is crystallographically impossible except as the result of the combination of these two different forms.

The form $i-2$ is a special case of the general form $i-n$ or $\infty c: n a: a$. When $n$ is some number less than 2, and greater than 1 , there must be twe planes answering the given conditions in each sectant, and twelve in all. Together they form the dihexagonal, or twelve-sided, prism. This prism bevels the edges of the prism $I$, and the vertical edges are of two kinds, axial and diagonal. The values of $n$ must lie between 1 and 2 ; some of the occurring forms are $i-\frac{4}{3}, i \frac{5}{4}$, etc.

Hexagonal pyramids, or quartzoids.-The symbol 1=c:a:a belongs to the twelve planes of the unit pyramid, f. 148, while the general form $m=m c: a: a$ includes all the pyramids in this series where the length of the vertical axis is some multiple of the assumed unit length. As in the tetragonal system, when $m$ diminishes, the pyramids become more and more obtuse, and the form passes into the basal plane when $m$ is zero; while as $m$ increases, the pyramids become more and more acute, and finally coincide with the prism $I$. These pyramids consequently replace the basal edges between $O$ and $I$, f. 149, and with them form a vertical zone of planes.

The pyramids of the $m-2$ series have the same relation to those of the $m$ series, just described, that the prism $i-2$ has to the prism $I$. They replace the basal edges between $i-2$ and $O$ (f. 145), and as the value of $m$ varies, give rise to a series or zone of planes between these limits.

The pyramids of both the first ( $m$ ) and the second ( $m-2$ ) series are well shown in f . 150 , of apatite. In the first series there are the pyranids $\frac{1}{2}, 1$, and 2 ; and in the second series the pyramids 1-2, 2-2, and 4-2. The cor

responding prisms $I$ and $i-2$ are also shown, and the zones between each of them and the basal plane $O$ are to be noticed. Attention may also be called to the fact, exemplified here, that the pyramid 2-2 truncates the vertical edges of the pyramid 2 ; also 1-2 truncates the vertical edges of 1 ; while the latter form (1) also truncates the vertical edges of $\frac{4}{3}-2$, as is seen in f. 147.

Dihexagonal pyramids, or Berylloids.-The general form $m c: n a: a$ gives the largest number of similar planes possible in this system, which is here obviously twenty-four, that is, two in each of the twelve sectants. These pyramids correspond to the prisms of the i-n series, and form the dihexagonal pyramids, or berylloids, as in f. 151.

The berylloid has three kinds of edges : the axial edges $X(f .151,152)$, connecting the apex with the extremity of one of the axes; the diagonal edges $Y$, and the basal edges $Z$

In the upper pyramid, one of these two planes for each sectant may be distinguished as the right, and the other the left, as lettered in f. 152; and the same, after inverting the crystal, for those of the other pyramid. It is to be observed that in a given position of the form, as that of f .151 , the right

of the upper pyramid will be over the left of the lower pyramid, and the reverse. Fig. 153 represents the planes of such a form $m$ - $n$ combined with the unit prism $I$, and the planes are lettered $l, r$, in accordance with the above. In f. 154 , of a crystal of beryl, the prism $I$ is combined with the pyranids 1, 2, 2-2, and the berylloid $3-\frac{3}{2}$.

## B. Hemihedral Forms.

I. Vertically Direct.-The planes of the upper range of sectants being in the same vertical zone severally with those below.
(A). Hemiholohedral.-Half the sectants having the full number of planes:

1. Trigonal pyramids.-The diametral pyramid $m-2$ is sometimes thus hemihedral, as in the annexed figure (f. 155) of a crystal of quartz, in which there are only three planes, 2-2 at each rextremity, and each of those above is in the same zone with one below. The completed form would be an equilateral and symmeurical double three-sided pyramid.

2. Trigonal prisms. -The occurrence of three out of the six planes of the prism $I$, or $i-2$, produces a three-sided prism. The prism $l$ is thus hemihedral in tourmaline (f. 156, a top view of a crystal), and the prism $i-2$ in quartz. Both these forms properly belong to the Rhombohedral division.
3. Ditrigonal prisms.-An hexagonal prism hemihedral to the dihexagonal prism occurs in quartz and tourmaline, the hexagonal prism sometimes having only the alternate vertical edges berelled, as in f. 185, and f. 186, p. 40.
(B). Holohemihedral.-All the sectants having half the full number of p.anes:
4. Hemi-dihexagonal pyramids.-Each sectant has one out of the two planes of the dihexagonal pyramid (f. 151, 153); this is indicated by
the shading in f .157 . The occurring plane may be the right above and left below, or left above and right below, and the form accordingly

either $r l m-n$, or $l r m-n$. Examples of the first of these oceur in f. 158, representing a crystal of apatite, the planes $o\left(3-\frac{3}{2}\right)$, and $o^{\prime}\left(4-\frac{4}{3}\right)$ being of this kind. This method of hemihedrism occurs only in forms that are true hexagonal ; it is often called pyramidal hemihedrism.
II. Vertically alternate, the planes of the upper range of sectants being in zones alternate with those below.
(A) Hemiholohedral forms, or those in which half the sectants have the full number of planes as in the

## Rhombohed́ral Division.

1. Rhombohedrons, and their relation to Hexagonal forms.-The rhombohedron is derivable from the hexagonal pyramid by a suppression of the alternate planes and the extension of the others. In f. 159 , if the shaded planes in front and the opposite ones behind are suppressed, while the others are extended, a rhombohedron will be derived. This is further shown in f .160 , where the hexagonal pyramid is represented within the rhombohedron. Another similar rhombohedron, complementary to this, would result from the suppression of the other alternate half of the planes. One of these rhombohedrons is called minus, and the other plus (f. 161, 162). The form in $f .148$ is made up, under the rhombohedral system, of $+R$ and $-R$ (or +1 and -1 ) combined, as in the annexed figure (f. 163), of a crystal of quartz.


Fig. 164 shows the combination of the rhombohedron with the prism $I$; in $f .165$ the former is more developed, and it finally passes into the com
plete rhombohedron, f. 161. In f. 166 the rhombohedral planes occur on the alternate angles of the diagonal prism i-2.

The symbol of the unit rhombohedron as referred to the hexagonal system is $\frac{1}{2}(c: a: a)$, a second rhombohedron may be $\frac{1}{2}(2 c: a: a)$ and so on; it is, however, more simple to write only $+R$ or $-R$, and $+2 R$ or $-2 R$, and so on; or, where there is no confusion with the symbols of hexagonal forms, as $+1,-1$, and $+m,-m$.


This hemihedrism resulting in the rhombohedron is analogous, in the alternate positions of the planes above and below, to that producing the tetrahedron in the isometric system. But owing to the fact that there are three lateral axes instead of two, the rhombohedron has its opposite faces parallel, unlike the tetrahedron.
 the rhombohedron +1 ; $\frac{2}{8}$ to the rhombohedron $+\frac{2}{8}$, having the vertitical axis $\frac{2}{3} c$; $O$ is the basal plane, or mathematically the rhombohedron 0 , the vertical axis being 0c. $I$ is the hexagonal prism $\infty: 1: 1$, or more properly a rhombohedron with an infinite axis, $\infty c$. On the opposite side of $I$ the planes are rhombohedral, but belong to the minus series; $-\frac{9}{2}$ has the vertical axis $\frac{9}{2} c ;-4,4 c ;-2,2 c ;-\frac{2}{8}, \frac{2}{8} c$, this last being complementary to
 $+\frac{2}{8}$, and the same identical form, except that all the parts are reversed. Fig. 168, $A-E$ ' represent different rhombohedrons of the species calcite: $A$, the rhombohedron 1 ; $B,-\frac{1}{2} ; C,-2 ; D,-\frac{8}{4} ; E, 4$; having respectively for the vertical axis, $1 c, \frac{1}{2} c, 2 c,{ }_{4}^{5} c, 4 c$, with $c=0.8543$, the lateral axes being made equal to unity. In f. 169 the rhombohedron 2 (or $2 R$ ) is combined with -1 (or $-R$ ), the latter truncating the terminal edges of the former.

In relation to the series of + and - rhombohedrons it is important to note that, since the position of $-\frac{1}{2} l$ is that of the vertical edge of $+R$, in combination with it, it truncates these edges. Similarly $+\frac{1}{4} R$ truncates the same edges of $-\frac{1}{2} R$, and so on.

Also $+R$ truncates the edges of $-2 R$, and $-R$ the edges of $+2 R$ (f. 169), $-2 R$ truncates the edges of $+4 R$, and so on.
2. Scalenohedrons ; forms hemihedral to the dihexagonal pyramid.-As the rhombohedron is a hemihedral hexagonal pyramid or quartzoid, so a scalenohedron is a hemihedral dihexagonal pyramid or berylloid. The method of hemihedrism is similar by the suppression of the planes of the aiternate sectants, as indicated by the shading in f. 170 (analogous to f. 159) and the extension of those of the other sectants. A scalenohedron is

represented in f. 171, a hexagonal double pyramid with a zig-zag basal outline, and three kinds of edges; the shorter terminal edge $X$, the longer terminal edge $Y$, and the basal edge $Z$; the lateral axes terminate in the middle of the edges $Z$. There are plus and minus ${ }^{\text {s scalenohedrons, as }}$ there are plus and minus rhombohedrons, and they bear the same relation to each other.

The relations of the form to replacements of the rhombohedron are illustrated in the other figures. Fig. 172 represents a rhombohedron ( +1 or $R$ ) with its basal edges bevelled ; and this bevelment, continued to the obliteration of the planes $R$, produces the scalenohedron shown by the dotted lines. The scalenohedron in f. 171, 172 has the vertical axis equal to $3 c$, or three times as long as that of $R$, the lateral axes of both being equal ; and hence it is that the planes are lettered $1^{2}$, the 1 referring to the rhombohedron and the index ${ }^{3}$ being the multiple that gives the value of the vertical axis of the scalenohedron.

In f. 173 there are two scalenohedrons of the same series,
 viz., $1^{0}, 1^{3}$, combined with the rhombohedrons $R(\mathrm{or}+1)$ and +4 . Fig. 174 shows the scalenohedron - $1^{3}$ combined with the rhombohedron -4 (or $-4 R$ ); and 175 , the same with the rhombohedron $5(+5 \mathrm{R})$.

Other scalenohedrons replace the basal angles of a rhombohedron by two similar planes (f. 176) ; or bevel the terminal edges; or replace the terminal solid angles by six planes, two to each terminal edge, or to each
rhombohedral face; a id they will be relatively + or - , accurding to their position in one or the other set of sectants, as has been explained. Fig. 17\% represents the top view of a crystal of tourmaline. It contains the rhomber



Tourmaline.
hedral planes, $R, \frac{5}{2}, \frac{11}{2},-\frac{1}{2},-\frac{7}{8},-\frac{5}{4},-2$, aloug with the scalenohedrons $-\frac{1^{2}}{2}$, $-\frac{1}{2}^{3},-\frac{1^{6}}{}{ }^{6}, 1 \frac{4}{3}, 1^{2}$, and also two others bevelling the terminal edges of the rhombohedron $R$.

The scalenohedrons $-\frac{1^{2}}{}{ }^{2},-\frac{1}{2}{ }^{3},-\frac{1}{2}{ }^{5}$, bevel the basal edges of the rhombohedron $-\frac{1}{2}$; and consequently the lengths of the axes are respectively $2,3,5$ times that of the rhombohedron $\frac{1}{2}$, and hence, equal $1 c, \frac{3}{2} c, \frac{\hbar}{2} c$. Every scalenohedron corresponds to a hevelment of the basal edges of some rhombohedron-and that particular one whose lateral ejges are parallel to those of the scalenohedron. The symbols for them according'y are made up of the symbol of the rhombohedron and an index which expresses the relation oi its vertical axis as to length to that of the rhombohedron, according to a method proposed by Naumann. (See p. 72.)


Corundum.

Hexagonal pyramids of the $m$-2 or diagonal series occur in many rhombohedral species; as $f .178$ of corundum, which contains $\frac{4}{3}-2(r), 4-2, \frac{28}{3}-2$ (for $9-2$ on the figure read $\frac{28}{3}-2$, Klein), along with the rhombohedron 1 , and the basal plane $O$; also f. 167, in which is the pyramid 2-2. Hemihedral forms of the same pyramids (of the kind described on p. 34) are met with in rhombohedral species, but only such as have also tetartohedral modifications. Hemihedral forms of the hexagonal and dihexagonal prisms (p.34) are also characteristic of some rhombohedral species, and of those that have either tetartohedral or hemimorphic modifications.

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Fig. 179 illustrates the relative positions of the zones of the + and - rhombohedrons, and diagonal pyramids $m-2$ alternating with regions of + and - scalenohedrons in the scheme of the rhombohedral system. The figure is supposed to be a top view. It is similar to f. $152, \mathrm{p} .34$, and like that contains the upper planes of the dihexagonal pyramid; but these are divided between a plus and a minus scalenohedron, those planes marked + being the former, and the others ( - ) the latter. The three lateral axes are lettered each $b b$. The position of the $+m R$ zone of planes (or plus rhombohedrons) relative to the scalenohedrons is shown by the lettering $+R$; of the $-m R$ zones (or minus rhombohedrons) by $-R$. The position of the vertical zone of $m-2$, or diametral pyramidal planes, is indicated by the letter $d$. The order of succession, beginning with one of the plus interaxial sectants (the one in the medial line below) and numbering it I, is as follows:
(2) Zoue of plus rhombohedrons, $+m R$.
(3) Plus scalenohedrons, or planes of the general form $+m^{\mathrm{n}}$.
(4) Zone of diagonal pyramids, $m-2$.
II. $\left\{\right.$ (5) Minus scalenohedrons, or planes of the general form $-m^{\text {n }}$.
(6) Tone of minus rhombohedrons, $-m \mu$.
(7) Minus scaleuohedrons, $-m$ ".
(8) Zone of diagonal pyramids, $m$ - 2 .
III. $\left\{\begin{array}{l}\text { (9) Plus scalenohedrons, }+m^{2} \text {. } \\ \text { (10) } \\ \text { (11) } \\ \text { Zone of plus scalenohedrons, },+m^{n}\end{array}\right.$. $+m R$.
(12) Zone of diagonal pyramids.

And so on around, as the figure illustrates. In the loveer pyramid the order of succession is the same; but the plus planes are directly below the minus of the above view of the upper pyramid.

The plus scalenohedrons have the pyramidal edge over the $+m R$ section, the more obtuse of the two (or edge $Y$ ); and the minus scalenohedrons have that edge the less obtuse (or edge $X$ ), and that over the $-m R$ section the more obtuse (or edge $Y$ ).
B. Holohemihedral forms, or those in which all the sectants have half the full number of planes (as shown by the shading in f. 180).

Gyroidal, or trapezohedral forms.-Of the planes, in f. 181 there would occur only those lettered $r, r$, above and below; or those lettered $l, l$, and, uniike f. 157 , the planes above and below are not in the same zone. The

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form is consequently gyroidal, the planes being inclined around the prism, both above and below, and in the same direction at the two extremities. It is also called plagihedral. The symbol for the planes is $\mathrm{rr} m-n$, or $U m-n$, according as the occurring planes of the two in the same sector are the right or the left. Fig. 182 is an example of $l l 6-\frac{8}{5}$ in the species quartz.

## C. Tetartohedral Forms.

These forms are hemihedral to the Rhombohedron.
(A) Holomorphic forms, like the preceding hemihedral, the planes occurring equally in the upper and lower range of sectants.

1. Rhombohedral tetartohedrism.-Occurring planes the alternate of those mentioned on page 35, that is, the alternate planes $r$ of one base, and $l$ of the other. They are the $r$ of three alternate sectants above, and
the $l$ of three sectants below alternate with these. A form of this kina consists of six equal planes, equally spaced, and hence, equal in inclina tions, and is therefore, in the completed state, a rhombohedron. It occure in menaccanite or titanic iron, and in quartz (f. 183, planes $13-\frac{1}{1} \frac{3}{2}$ ).
2. Gyroidal or trapezohcdral tetartohedrism.-Occurring planes the alternate of those lettered $r$ or $l$ in $\mathrm{f} .153, \mathrm{p} .34$, that is, the alternate planes $r$, or alternate $l$, of both bases.


In f. 185, the planes $o^{1}, o^{11}, o^{11}, o^{\text {iv }}, o^{7}\left(4-\frac{4}{3}, 5-\frac{5}{4}, 6-\frac{8}{5}, 8-\frac{8}{7}, 3-\frac{3}{2}\right.$, the first four right, the last left) are examples. The upper and lower of a kind adjoin the same diametral plane, but are on opposite sides of it, and therefore the three sectants containing planes below are alternate with the three above. The solid made of these six planes (f. 184) has trapezoidal faces, and is called a trigonotype by Naumann.

The tetartohedral planes on quartz and cinnabar have a remarkable connection with the circular polarization which is characteristic of them both, and which is further explained elsewhere (p. 142).
(B) Hemimorphic forms; the planes occurring either in the upper or the lower range of sectants and not in both.

There are two kinds of forms: (1) the hemi-rhombohedron, and (2) the

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From the same point of view, the ditrigonal prisms in tourmaline and hemi-scalenohedron. Fig. 186 illustrates each of these forms. The form $R$ is properly hemihedral at the two extremities, its planes being very large at one, and quite small at the other. So with $-\frac{1}{2}$. Another rhombohedron, -2 , occurs only at the upper extremity. Again, $\frac{1_{2}{ }^{6}}{}{ }^{6}$ is a hemi-scalenohedron, the upper six planes being present, but not the lower.

The prism $I$ in this figure is hemihedral, as explained on p. 34. It is not tetartohedral to the hexagonal system in the ordinary view. But since in a vertical zone $+m R, \infty R,-m R$, the $\infty R$ may be regarded as the infinite term of either the $+m h$ series, or else the same of the $-m R$ series; and as this view accords with the tetartohedral character of the $m R$ series in all such crystals, it might be ranked among tetartohedral forms.
quartz are tetartohedral, since they may be regarded as either plus or minus tetartohedral scalenohedrons, with an infinite vertical axis.

Variable elements.-In the hexagonal system the same elements are varnable as in the tetragonal (see p. 30). In other words, the position of the vertical axis is fixed, but (1) a certain length must be assumed as the unit in a given species, and also (2) the position of the lateral axes must be fixed, for, as in $\mathrm{f} .144,145$, either of the hexagonal prisms may be made $I$ and the other $i-2$.

The general characteristics of this system which the student must be acquainted with are: (1) The planes constantly occur in threes or sixes, or their multiples; (2) The frequency of the angles $120^{\circ}$ and $150^{\circ}$ in the prismatic series; (3) The rhombohedral cleavage, common in species belonging to the rhombohedral division. It is also important to note that many forms apparently hexagonal really belong to the orthorhombic system, being produced by twinning parallel to the vertical prism; e.g., the apparently hexagonal prisms of aragonite. The close relation of the two systems is spoken of elsewhere (p.46).

The planes of symmetry for the holohedral forms are analogous to those in the tetragonal system; that is, one principal plane of symmetry normal to the vertical axis, and six others intersecting in this axis. These last belong to two sets, the planes of the one cutting each other at angles of $60^{\circ}$, and diagonal to those of the other.

## IV.-ORTHORHOMBIC SYSTEM.

In the Orthorhombio system the three axes are unequal $\dot{c}, \bar{b}, a \mathfrak{a}$; of these $\dot{c}$ is the vertical axis, $\bar{b}$ is made the longer of the two lateral axes, or the macrodiagonal axis, and ă the shorter lateral, or brachydiagonal, axis.*

The different occurring forms, deduced as before from the general expression, are:


#### Abstract

The abridged symbols need very little explanation additional to that given on p. 25. As before, only the essential part of the symbol is given ; $m$ is written first, and refers in all cases to the vertical axis (c), and $n$ refers to one of the lateral axes, whether the longer ( $\bar{b}$ ) or the shorter ( $\check{a}$ ) is indicated by the sign placed over it, as $\bar{n}$ or $\check{n}$. When $n=\infty$, this is indicated by the $i$ hitherto used, and the sign is placed over it, $\bar{i}$, or $\check{i}$, with the same signiflcation. These correspond to the symbols used by Naumann, as follows: $0=0 P ; i \cdot i=$ $\infty P \bar{\infty} ; i-i=\infty P \bar{\infty} ; \infty P \bar{n}=i \cdot \bar{n} ; m P \bar{\infty}=m-\bar{i} ; m P=m ; m \cdot \bar{n}=m P \bar{n}$, eto.


[^4]
## A. Holohedral Forms.

Pinacoids.-The final case mentioned in the above enumeration em braces, as before, the two basal planes, or basal pinacoids; the one preceding it includes the two planes parallel to the vertical and macrodiagonal axes ( $c$ and $b$ ), called the macropinacoids, and the next above includes the planes parallel to the vertical and brachydiagonal axes ( $c$ and $a$ ), called the brachypinacoids. These three sets of planes together form the solid in f. 188 , which is called the diametral prism. In consequence of the inequality of the different pairs of planes there are only four similar edges in any set; thus four similar vertical edges; four macrodiagonal basal edges, two above and two below, between 8 and $i-\bar{\imath}$; and similarly four brachydiagonal basal edges between $O$ and $i-\imath$; the eight solid angles are all similar.


Prisms.-The form $\infty c: b: a$, or $I$, includes the four planes of the unit prism which, in combination with $O$, is seen in f . 187. In this case the eight basal edges are similar, being made in each case by a similar pair of planes $O$ and $I$. Of the vertical edges there are two pairs, those at the extremity of the axis $\check{a}$, which are obtuse, and those at the extremity of $\bar{b}$, which are acute. Similarly, there are two sets of basal solid angles, four in each; for though each solid angle is formed by the meeting of the same three planes, the angles are different in the two cases, The form $I$ replaces the four similar vertical edges of f. 188 ; the macropinacoids $i-\bar{i}$ truncate the obtuse vertical edges of the prism $I$, and the hrachypinacoids $i$-ǐ truncate the acute vertical edges of $I$, as shown in f. 189 .

There are two other series of prisms with symbols $\infty c: n b: a$ and $\infty c: b: n a$. In the latter series the axis $b$ is made the unit; the reason for this will be obvious when the relations of the two forms are explained.

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 The prism $I$ meets both axes $a$ and $b$ at their unit lengths; as in f. 187. If, now, the prismatic planes meet the longer lateral axis (b) at a greater distance, a prism is formed such as that in f . 190 , whose symbol is $i$, , or $\infty c: 2 b: a$. This is a macrodiagonal prism; and others might have the symbols $i-\overline{3}(\infty c: 3 b: a), i-\overline{4}(\infty c: 4 b: a)$, and so on, or in general $i-\bar{n}$.

If $n$ becomes less than unity, the case shown in f. 191 arises where the inner prism has $n=\frac{1}{2}$, and the symbol is $i-\frac{T}{2}(\infty) c: \frac{1}{2} b: a$ ), still retaining $c \check{c}$ as the unit axis. For convenience of reference, however, the principle before explained (p.11) is made use of, and the plane is called $\infty c: b: 2 \pi$, , or $i-\frac{\Sigma}{\mathbf{i}}$
these expressions and those before given being identical, except that in the latter case $b$ is the unit axis. By this method the use of any fractions less than unity is avoided. The inner prism $i-\frac{T}{2}$, indicated by dotted lines in $f .191$, ther becomes the onter prism or $i-2$. The prisms of the general form $i-n$, are called brachydiagonal prisms.

The prisms $i-\bar{n}$ bevel the front and rear (obtuse) edges of the prism $I$, f. 192, and the prisms $i-\check{n}$ bevel the side (acute) edges as in f.193. Further, the former, $i-\bar{n}$, replace the edges between $i-\bar{\imath}$ and $I$ (f. 194), while the $i-n$ prisms replace the edges between $i-\imath$ and $I$ (f. 194).

This series of planes (f. 194), from $i-\bar{\imath}$ to $i-\bar{\imath}$, is another example of a zone; all the planes make parallel intersections with each other, being alike in that they are parallel to the vertical axis.


Domes.-The form $m c: \infty b: a$ includes the four planes which are parallel to the macrodiagonal axis, and meet the vertical axis at variable distances, multiples of the unit length (see f. 34, p. 11). An example of them in combination with $i-\check{\imath}$, the brachypinacoid, is shown in f. 195. These planes are called macrodomes (see also f. 196).

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The form $m c: b: \infty a$ includes four analogous planes, which differ in this respect, that they are parallel to the brachydiagonal axis, and are hence called brachydomes (see f. 35, p. 11). In this case, the longer lateral axis is taken as the unit. Fig. 197 shows two such brachydomes, $1-\check{\imath}$ and $2-\check{\imath}$, in combination with other forms. (See also f. 198.) The word dome, used here and above, is derived from $\delta o \mu \eta$, or domns, a house, the form resem. bling the roof of a house.

The combination of $1-\bar{\imath}$ with $1-\tau$ is shown in f. 199, forming a rectangular octahedron, and in f. 200 they are shown replacing the solid angles formed by $I$ and $O$, as in f. 188. As either of the three directions may be made the vertical, it is evident that these domes differ from vertical prisms only in position.

The occurrence of these domes in combination with the other forms, $O$, $i-\bar{i}, i-\ell, I$, affords an illustration of the law of symmetry that all similar parts must be modified alike. Thus in f. 187, as has been shown, there are two sets of solid angles, four in each; one set is replaced by the four planes of the form $m-i$, and if one is, all must be ; and the other set (lateral) is replaced by the four planes of the form $m \cdot \check{\iota}$, f. 200.

Octahedrons (or Pyramids). -The symbol $c: b: a$ (1) belongs to the unit octahedron (f. 201). It replaces the edges between the prism $I$ and the basal plane $O$ (f. 202). It also replaces

the eight similar solid angles of the diametral prism, as in f. 203. This is a special case of the form $m c: b: a$, in which $m$ may have values varying from 0 to $\infty$. Fig. 208, of sulphur, shows a zone of such planes, of the general symbol $m c: b: a$, with $m=\infty$ for $I$; also, $m=1, m=\frac{1}{2}, m=\frac{1}{8}$, $m_{0}=\frac{f}{6}$, and finally $m=0$, for the basal plane $O$.


The general form in this system, consisting of eight similar planes, may lie written either $m c: n b: a(m-\bar{n})$ or $m c: \bar{b}: n a(m-\breve{n})$. The relation between the two is the same as that between the prisms $i-i$; and $i-n$. Thus, in $f$. 204, one plane of the octahedron $2 c: 2 b: a(2-\overline{2})$ is given, and also one plane of another octahedron or pyramid, whose symbol is $2 c: b: a$ (2). If $n$ becomes less than unity, as $\frac{1}{2}$, the plane has the symbor $2 c: \frac{1}{2} b: a\left(2-\frac{T}{2}\right)$. In order to avoid this use of fractions the symbol is written $4 c: b: 2 a$, that is, $4-5$. The plane is shown in f .205 , in its two positions corresponding to $2 c: \frac{1}{2} b: a$, and $4 c: b: 2 a$, the two being crystallographically identical.

Thus there are two series of pyramidal planes: a macrodiagonal ( $m-\bar{n}$ ) where the shorter axis is taken as the unit, and a brachydiagonal ( $m-n$ ), where the unit is the longer lateral axis; and between the two lie the unit octahedron (1) and those of the $m$ series, just as the prism $I$ lies between the prisms $i-\bar{n}$ and $i-n$. The macrodiagonal planes 1-2 and 2-5 are shown in f. 206 and f. 207. It is also seen in f. 207 that the planes $2-\overline{2}, 2-\bar{i}, 2-\overline{2}$ all make parallel intersections with each other and with $i-\check{2}$, being an example of a zone where the ratios of the vertical axes are the same. Further orthorhombic forms are displayed in f. 208, of sulphur, already referred to The full symbol of the plane 1-3 is $c: b: 3 a$.


Sulphur.

## B. Hemihedral Forms.

The hemihedral forms that have been observed are of two kinds: 1 , The vertically-oblique (p.14), producing monoclinic forms; and 2, the hemimorphic, in which the planes of the octahedrons or domes of one base have no corresponding planes at the opposite extremity. The former kind

is illustrated in f. 209, of the species chondrodite (var. humite, type III). Fig. 210 represents the holohedral form of the same; the planes $\frac{2}{8}-i, 1-\bar{\imath}$, $2-i$, are of macrodomes ; $\frac{4}{7}-\tau, \frac{4}{5}-\tau, \frac{4}{3}-v, 4-\imath$, of brachydomes ; and the others of various octahedrons, mostly in two vertical zones, the unit zone ( $m c: b: a$ ), and the $1: 2$ zone ( $m a: 2 b: a$ ). In f. 209 the alternate of the macrodomes and of the octahedral planes of the 1:2 zone are absent in the upper half of the form, and are present without those with which they alternate in the lower half. The crystal consequently resemblas one under the monoclinic system.

Datolite was formerly cited as a hemihedral orthorhombic species, but it has been found to be really monoclinic. Furthermore, ithas been recently shown by the author, by reference to the optical properties, that the chon
drodite of the second and third types (see p. 327) is not orthor hombic but monoclinic, and this must be true also of humite.*

Hemimorphic forms characterize the species topaz and calamine. The latter (inf. 211) has only the planes of a hemioctahedron at one extremity, and planes of hemidomes at the other. For the pyro-electric properties of such forms, see p. 169.

Variable elements.-In the orthorhombic system the lengths of the three axes are variable, though their position is fixed, and after these are fixed the choice of one for vertical axis must be arbitrarily made. In other words, given an orthorhombic crystal, the three rectangular directions are fixed, but two assumptions must be made which will mathematically determine the length of two of the axes in terms of the third. For instance, in a crystal, if certain occurring domes are adopted as the unit planes $1-\bar{\imath}$ and 1-乞, this will determine the relative lengths of the three axes, for which two measurements will be necessary; or, if an occurring octahedron is assumed as the unitoctahedron (1,) this alune will obviously fix the axes; but here, also, two independent measurements are necessary in order to enable us to calculate their length, as is explained later, p. 74. Having determined upon the relative lengths of the axes, one of these must be made the vertical axis $(c)$, and then, of the two remaining, the shorter will be the brachydiagonal (a), and the longer the macrodiagonal axis (b).

In deciding these arbitrary points, the following serve as guides: The habit of the crystals; the relations of the given species to those allied in composition; the cleavage, which is regarded as pointing to that form which is properly fundamental; and other considerations. How arbitrary the choice generally is is well shown by the fact that, in a considerable number of species belonging to this system, different lengths of axes, as also different positions for them, have been adopted by different authors. Where an optical examination can be made of an orthorhombic crystal, the results show what the true position of the axes is, in accordance with the principles proposed by Schrauf. This subject is alluded to again in its proper place (p. 151).

The general characteristics of the crystals of this system are not so marked as those of the preceding systems. The kind of symmetry should be well understood, though, as remarked on p. 50, crystals which are in appearance orthorhombic may be really monoclinic; the true test of the system is to be found in the three rectangular axial directions. A prismatic habit is very common, the prisms (except the diametral prism) not being square, also the prominence of some of the most commonly occurring macrodomes and brachydomes; a prismatic cleavage is common, and often a cleavage exists parallel to one of the pinacoids (e.g., $i-\bar{z}$ ) and not to the other, which conld not be true in the tetragonal system; similarly the planes $i-\bar{\imath}, i-\zeta$ are sometimes physically different, e.g., in regard to lustre.

As has already been remarked, forms apparently hexagonal are common among certain species belonging to this system ; this is true in those cases

[^5]where the prism has an angle approximating to $120^{\circ}$. It is immediately evident, as is explained more thoroughly in the chapter on compound crystals, that if three individual crystals are united each by a prismatic face, when the prismatic angle is near $120^{\circ}$, they will form together a six-sided prism, approximating more or less closely to a regular hexa gonal prism. Similarly, under the same circumstances, the correspond ing pyramids will thus together form a more or less symmetrical hexagonal pyramid. This is illustrated by the accompanying figures of witherite, where the prismatic angle is $118^{\circ}$, $30^{\prime}$. It need hardly be added that this is true in general, not only of the vertical prism, but also of a macrodome or brachydome, having an angle near $120^{\circ}$. The optical relations connected with this subject are alluded to elsewhere, p. 151.

Planes of Symmetry.-The three diametral planes
 are planes of symmetry in this system, and they are the only ones.

## V.-MONOCLINIC SYSTEM.

In the Monoclinio system the three axes are unequal in length, and while two of them have rectangular intersections, the third is oblique. The position usually adopted for these axes is as shown in f. 214, where the vertical axis, $\dot{c}$, and lateral axis, $b$, make retangular intersections, The same is true of $b$ and $\dot{a}$, while $\dot{c}$ and $\dot{a}$ are oblique to one another.

The following is an enumeration of the several distinct forms possible in this system. deduced, as be-
 fore, from the general expression :

$$
\left\{\begin{array}{llll}
-m c: n b: a & {[-m-n]} \\
+m c: m b: a & {[+m-n]} \\
-m c: b: n a & {[-m-n]} \\
+m c: b: n a & {[+m-n]} & \left\{\begin{array}{ll}
-m c: \infty b: a & {[-m-i]} \\
+m c: \infty b: a & {[+m-i]} \\
\infty c: n b: a & {[[i n]} \\
\infty c: b: n a & {[i-n]} \\
-n c: b: a & {[-m]}
\end{array} \begin{array}{cc:c:c} 
& {[1]} \\
-c: b: a & {[-1]} & \infty c: \infty b: a & {[i-i]} \\
+m c: b: a & {[+n]} & \infty c: b: \infty a & {[i-i]} \\
+c: b: a & {[+1]} & 0 c: b: a & {[0]}
\end{array}\right. \\
m c: b: \infty a & {[m-i]} & &
\end{array}\right.
$$

The abridged symbols correspond to those in the orthorhombic system, explained on p. 42. The only point to be noted is that where $n$ or $i$ relates to the clinodiagonal axis, $\grave{a}$, this is indicated by ar accent placed over it, as $m-i, m-n$; but in $m-i$, and $m-n$, etc., $i$ and $n$ refes to the orthodiagonal axis. Naumann wrote these $m P \dot{\infty}$, and $m P i$, or else with the accent across the initial letter $P$. The minus signs are used in the same way as by Naumana (see p. 76).

Pinacuids.-As in the orthorhombie system, there are three pairs of pinacoidal planes: the base $O=0 c: b: a$; the orthopinacoid, parallel to the
ortho-axis (b) $\infty c: \infty b: a$, or $i-i$; and the clinopinacoid, parallel to the in clined axis $(a), \infty c: b: \infty a$, or $i-\imath$.

In the solid (f. 216) or diametral prism formed of these three pairs of planes, the four vertical edges are similar, and this is also true of the four edges between $O$ and $i-i$. . On the otherhand, the four remaining edges are of two sets; that is, the edge in front above is similar to the edge behind and below, for the angles are equal
 and inclosed by similar planes; but these edges are not similar to the remaining two, since, though the planes are the same, the inclosed angles are unequal to the former. Further, there are two sets of solid angles, two in front and two diagonally opposite behind, being alike obtuse angles, and the other four alike and acute.

Prisms.-In consequence of the similarity of the vertical edges of the diametral prism, they must all be replaced if one is ; this is done by the unit prism $I(\infty c: b: a)$, in f. 215, 217.


Of the other prisms, each obviously consist.ing of four planes, there are two series, the orthodiagonal, $i-n$, and clinodiagonal, $i-\grave{n}$, bearing the same relation to each other as the macro- and brachy-diagonal prisms in the orthorhombic system, in fact, the same explanation may be made use of here. Fig. 217, of a crystal of datolite from Toggiana, shows the pinacoid planes, as also the unit prism, $I$, and the clinodiagonal prism, $i-2$.

Clinodomes. -The form $m-\grave{\imath}(m c: b: \infty a)$ includes the four planes parallel to the clinodiagonal axis, and meeting the others at variable distances. They are analogous to the brachydomes of the orthorhombic system. There are four of these planes, because the two axes, $c$ and $b$, make rectangular intersections. This is also seen in f. 218, sinee, as has been remarked, the four clinodiagonal edges in f. 215 are similar, and hence are simultaneously replaced by these clinodomes.


Orthodomes.-Of the general form, $m c: \infty b: a$, there are two sets of planes, two in each (hemi-orthodomes), both of which are alike in that they are parallel to the orthodiagonal (b) axis (see f. 219). They are unlike, however, in that two are opposite an obtuse angle, and two opposite the acute angle. Consequently these two pairs of planes are distinct, and must occur
independently of each other. To distinguish between them, those belonging to the obtuse sectants receive the minas sign $(-m-i)$, and those belonging to the acute sectants the plus sign $(+m-i), f .219$. This same point is illustrated by f. 220 , where, as has been remarked, the obtuse edges, above in

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front, and below behind, are similar, and are hence replaced by planes of the $-m-i$ series, while the remaining two (f. 221), are also similar, and are replaced by $+m-i$ planes.
Hemi-octahedrons.-The same distinction of plus and minus belongs to all the pyramidal planes, and the signs are used in the same way. Fol each form there are only four similar planes.

The $m$ series is that of the unit octahedrons,-properly hemi-octahedrons, or hemi-pyramids $+m$ and $-m$. The form made up of +1 and -1 is seen in f .223 , and in f .222 the same planes are in combination with the three pinacoids.

The general form, $+m-n,-m-n$, and $+m-\grave{n},-m-\grave{n}$, give each four similar planes. They bear exactly the same relation to each other as the $m-\bar{n}$ and $m-n$ of the orthorhombic system, so that no additional explanation is needed here in regard to them.

The figure (f. 217) of datolite may be referred to for illustrations of the different forms which have been named. There are here three different clinodomes $\frac{4}{3}-i, 2-i$, and $4-i$, each comprising four planes; a minus hemiorthodome (opposite the obtuse angle), $-2-i$, and also a plus orthodome, $+2-i$ (these two planes are quite distinct, though numerically the symbols are the same) ; moreover, of hemi-octahedrons of the unit series, there are -4 , $-\frac{4}{3}$, and $+4,+2,+\frac{4}{3},+1,+\frac{4}{8},+\frac{2}{8}$; also of orthodiagonal pyramids, $-4-2$, $-6-3$, also $+2-2$, and of clinodiagonal planes, $-8-\frac{2}{2}$, and $+12-\frac{3}{2}$. A careful study of a few such figures, especially with the help of models, will give the student a clear idea of the symmetry of this system. It will be noticed that all the planes above in front are repeated below behind, and those below in front appear again above behind. More important than this, it. will be seen that the clinodiagonal dianetral plane divides the crystal into two symmetrical halves, right and left; in other words, as remarked later, it is a plane of symmetry.

Hemihedral forms occur of a hemimorphic character, in which the planes about the opposite extremities of the vertical axis are unlike; thus, the planes of one or more hemi-pyramids may occur at one extremity, without those corresponding at the other, as in tartaric acid, ammonium tartrate, etc.

With many monoclinic crystals the obliquity is obvious at sight ; but with many others it is slight, and can be determined only by exact measurements.

In datolite it is only six minutes. The character of the symmetry exhibita further the obliquity. But, as seen above, both + and - planes of the same value do occur together, and though they are really distinct yet they may give a monoclinic crystal the aspect of an orthorhombic crystal. On the other hand, true orthorhombic crystals may be hemihedral, and thus may be monoclinic in the character of the symmetry (p. 45).

Variable elements.-In the monoclinic system, the only element which is fixed is the position of the orthodiagonal axis (b) at right angles to the plane in which the other axes must lie. The lengths of these axes must obviously be assumed in the same way as in the preceding system; but, further than this, their position in the given plane, and the angle they make with each other, are both arbitrary; in other words, any plane in the zone at right angles to the clinopinacoid may be taken as the base $(O)$ and any other as the orthopinacoid ( $i-i$ ). The existence of a prismatic cleavage, or one parallel to a plane in the orthodiagonal zone often points to the planes which are really to be considered fundamental. In many cases it is considered desirable to assume an angle near $90^{\circ}$ as the angle of obliquity, so as to show the degree of divergence from the rectangular type. It need hardly be added that authorities differ widely both as to the position and lengths given to the axes of the same species.

Plane of symmetry.-Monoclinic crystals have but one plane of symmetry, the diametral plane in which the vertical and clinodiagonal axes lie, that is, the plane parallel to the clinopinacoids. The maximum number of similar planes for any form is four, and it will be noticed that there is no single form which alone can enclose a space, or form a geome trical solid.

## VI.-TRICLINIC SYSTEM.

In the Triclinic system the three axes are unequal, and their intersections are mutually oblique. In consequence of this fact, there is no plane of symmetry. Only diagonally opposite octants are similar; there can consequently be only two planes of any one kind. There are no truncations or bevelments, and no interfacial angles of $90^{\circ}, 135^{\circ}$, or $120^{\circ}$. The prisms are all hemiprisms, and the octahedrons tetarto-octahedrons.

The lateral axes are called the macrodiagonal $(\bar{b})$, and the brachydiagonal (ă). In f. 225 the diametral prism (made up of three pairs of different

planes) is represented, and in f. 224 the unit prism. To the latter is added (in f. 226) one plane -1 on two diagonally opposite edges, which are two out of the eight of the unit octahedron (f. 227). This octahedron, as will
be seen, is made up of four sets of different planes. The different kinds of planes are distinguished by the long or short mark over the $n$ ( $\bar{n}$ or $\check{n}$ ) and also by giving those which occur in the right-hand octants, in front, an accent; those above (in the obtuse octants) are minus, and the others plus. The form $m-n_{n}$ consequently may be $-m-n^{\prime}$, or $-m-n_{n},+m-n^{\prime}$, or $+n-n$; and similarly with $m-\bar{n}$. In f. 228 the unit prism is combined with a hemidome and a vertical plane parallel to the brachydiagonal section.

The forms, although oblique in every direction, may still be closely similar to monoclinic forms of related species.


The annexed figures are of triclinic species. In f. 229, of anorthite, of the feldspar group, the form is very similar to those of the monoclinic feldspar, orthoclase; in orthoclase, $O$ on the brachydiagonal (clinodiagonal) section is $90^{\circ}$, whence it is monoclinic, while in anorthite this angle is $85^{\circ}$ $50^{\prime}$, or $4^{\circ} 10^{\prime}$ from $90^{\circ}$, and this is the principal source of the diversity of angle and form.

Fig. 230 represents one of the crystalline forms of axinite, nearly all of which fail of any special monoclinic habit.

## MATHEMATICAL CRYSTALLOGRAPHY.

Introductory remarks on the proper symbol of each plane of a general crystalline form. -Hitherto the symbol $m c: n b: a$ has been employed to express the general position of all the planes comprising any crystalline form, and it has been shown that there are in some cases forty-eight similar planes answering to the general symbol, and in other cases only two. In order, however, to express the exact position of each individual plane belonging to such a form, it becomes necessary to resort to the methods of analytical geometry. As shown in f. 231, the portions of the axes, when the centre is the starting point, which lie above, to the right, and in front of the centre, are called plus $(+)$; the corresponding portions of the axes measured from the centre below, to the left, and behind, are called, for the
sake of distinction, minus ( - ). The planes of the first quadract (see also f. 232) are all positive $(+)$; the planes of the second positive ( + ) with reference to the axes $c$ and $a$, but negative ( - ) with reference to $b$; in the


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third, both lateral axes are negative ( - ); in the fourth quadrant the planes are positive in regard to $c$ and $b$, but negative with respect to $a$. The lower quadrants are respectively similar, except that the vertical axis is always negative. The symbols for each plane of the orthorhombic octahedron (f. 231), taken in the same order, will be as follows.

$$
\begin{aligned}
& \text { Above, }+c:+b:+a ;+c:-b:+a ;+c:-b:-a ;+c:+b:-a \\
& \text { Below, }-c:+b:+a ;-c:-b:+a ;-c:-b:-a ;-c:+b:-a
\end{aligned}
$$

The hexoctahedron ( $n a: n a: a$ ) may be taken as another example. The general symbol of the form of $\mathrm{f} .247, \mathrm{p} .64$, is $3-\frac{3}{2}\left(3 a: \frac{3}{2} a: a\right)$, but the symbol of each plane is distinct. The same principle applies here as in the other case. Several of the planes in f. 247 are numbered to allow of convenient reference to them as examples, the appropriate symbols are written below; the order in the symbols is the same as that uniformly used in the work: 1st, the vertical axis $(\dot{c})$; 2d, the lateral axis extending right and left (b) ; and 3d, the lateral axis, in front and behind (a).

$$
\begin{aligned}
& \begin{array}{l}
c \quad b \quad a \\
1=3 a: \frac{3}{2} a: a \\
2=\frac{3}{2} a: 3 a: a \\
3=a: 3 a: \frac{3}{2} a \\
4=a: \frac{3}{2} a: 3 a \\
5=\frac{3}{2} a: a: 3 a
\end{array}
\end{aligned}
$$

It will be evident from these examples that to express the position of an individual plane the numbers expressing its relations to the three axes must all be regarded, each with its appropriate sign; in other words, the values of $m, n, r$, in the general form, $m c: n b: r a$, must all be given, one of them being unity; $m$ always refers to the vertical axis, $c ; n$ to the lateral axis, $b ; r$ to the lateral axis, $a$; as has already been remarked, $a$ is usually made the unit axis. In the example last given the axes, being all equal, are all called $a$.

Reference must be made here to the method of lettering the axes adopted in this work. The usage of the majority of authors is followed, and the subject is ilfustrated in the following table.


It is certainly very desirable to indicate to which axis each letter refers by tho mark placed above it ; in doing which, we follow Klein's Einleitung in die Krystallbereuhnung.

## DETERMINATION OF PLANES BY ZONES.

The subject of zones has been briefly explained on page 4, and various examples have been pointed out. The principle is one of the highest importance, both practically, since it gives the means of determining the symbols of many planes without calculation, and also theoretically. The law of zones, which states simply that the planes of a crystal lie in zones, is one of the most important of the science, and second only to that of the rationality of the indices. The planes of a crystal thus may be said to be connected together by these zones, a single plane often lying in a large number of zones.

Parallelism in the combination edges, or mutual intersections of planes, is based upon some common geonetrical ratio, and this common ratio be longs to the symbols of all the planes of the zone.

All planes which lie in the same zone will give exactly parallel reflections with the reflective goniometer, as explained on p. 87. This is the only decisive test, and when possible should be made use of, since combination-edges often appear parallel when the planes forming them are not really in the same zone. Furthermore, inasmuch as parallel intersections are observed between planes of a zone only when they actually intersect, the goniometer may ofteu serve to detect the existence of zones not otherwise manifest.

In f. 194, p. 43, the planes $i-i, i-\overline{2}, I, i-2, i-\tau$, all lie in a vertical zone, and they are all obviously alike in this, that they are parallel to the vertical axis; in other words, the common value $\dot{c}=\infty$ belongs to them all. Again, in the zone $O, 1-\tau, 2-\imath$,
 $i-\imath$, etc. (f. 197, p. 43), the planes are alike in that they are all parallel to the brachydiagonal axis; in other words, $\breve{a}=\infty$ is true of all of them. Still again, the pyramidal planes $\frac{1}{2}, 1,2(f .150, \mathrm{p} .33)$, are also in a zone between $\delta$ and $I$, and here the ratio $1: 1$ for the lateral axes applies to all ; also, 1-2, 2-2, 4-2, are in a zone from $O$ to $i-2$, and for them the lateral axes have the ratio $1: 2$. In the case of an oblique zone, as $i-\check{-}, 3-z, 2-2$, 1 , etc. (f. 233), this fact is less evident on inspection, but is equally true, as will be seen later. The common ratio in this case is $n=r$.

Since all the planes of a zone have a common ratio, which has been
shown to be true in several examples but also admits of rigid prosf, it is evident that a plane which lies in tuoo zones has its position determined by that fact, since it must answer to two known conditions. In other words, the algebraic equation of a zone is known when the parameters of two of its planes are given, for they are sufficient to determine the common ratio, and by combining them the zone equation is obtained; and further, when the equations of two zones are given, combining them will give the equation, that is, the parameters, of the plane common to both.

The general equation, derived from Analytical Geometry, for any plane $m c: n b: r a$, making parallel intersections with the planes $m^{\prime} c: n^{\prime} b: r^{\prime} a$ and $m^{\prime \prime} c: n^{\prime \prime} b: r^{\prime \prime} c$ is,

$$
\frac{M}{m}+\frac{N}{n}+\frac{R}{r}=0 ; \text { in which }
$$

$M=n^{\prime} m^{\prime \prime}\left(n^{\prime} r^{\prime \prime}-n^{\prime \prime} r^{\prime}\right) ; N=n^{\prime} n^{\prime \prime}\left(r^{\prime} m^{\prime \prime}-r^{\prime \prime} m^{\prime}\right) ; R=r^{\prime} r^{\prime \prime}\left(m^{\prime} n^{\prime \prime}-m^{\prime \prime} n^{\prime}\right)$.
By substituting the values of the parameters of two given planes for $m^{\prime}$, $n^{\prime}, r^{\prime}$, and $m^{\prime \prime}, n^{\prime \prime}, r^{\prime \prime}$ in the zone equation, a derived equation is ohtained which expresses the relations between $m, n, r$ of all the planes of the zone. The form of the general zone equation is so symmetrical that the calcula tions are in any case quickly and easily made by a method analogons ts that used in Miller's system (as suggested by Prof. J. P. Cooke). If we write the parameters in parallel liues, repeating the first two terms, we have

$$
\begin{aligned}
& m^{\prime} \\
& m^{\prime \prime}
\end{aligned}, n^{\prime}, n^{\prime \prime} \times \begin{aligned}
& r^{\prime} \\
& r^{\prime \prime}
\end{aligned} \times \begin{aligned}
& m^{\prime} \\
& m^{\prime \prime}
\end{aligned} \times \begin{aligned}
& n^{\prime} \\
& n^{\prime \prime}
\end{aligned}
$$

- and it will be seen that the coefficients $M, N, R$ are found by multiplying together the parameters in the manner which the scheme indicates.
$M=m^{\prime} m^{\prime \prime}\left(n^{\prime} r^{\prime \prime}-r^{\prime} n^{\prime \prime}\right) . ~ N=n^{\prime} n^{\prime \prime}\left(r^{\prime} m^{\prime \prime}-m^{\prime} r^{\prime \prime}\right) . R=r^{\prime} r^{\prime \prime}\left(m^{\prime} n^{\prime \prime}-n^{\prime} m^{\prime \prime}\right)$.
Take, for example, the zone of planes between $i-\check{ }$ and 1 (f. 233). For $i-i, m^{\prime}=i, n^{\prime}=1, r^{\prime}=i$; for $1, m^{\prime \prime}=1, n^{\prime \prime}=1, r^{\prime \prime}=1(i=\infty)$; hence the scheme becomes

and for the several values of the coefficients

$$
M=i(1-i)=-i^{2} . \quad N=1(i-i)=0 . \quad R=i(i-1)=i^{2} .
$$

This reduces the zone equation to $m=r$ (after dividing by $i^{2}=\infty^{2}$ ), and to this all the planes of the zone conform. So also for the zone of $1-\zeta, I$, $3-\frac{\overline{3}}{2}, 1-\bar{i}$, etc., in f .234 . The parameters of the plane $I$ and $1-\bar{\imath}$ arranged as above give

$$
\begin{array}{lllll}
i & 1 & 1 & i & 1 \\
1 & i & 1 & 1 & i
\end{array}
$$

and the values of $M, N, R$ are $-i^{2},-i^{2}$ and $+i^{2}$ respectively. Hence the zone equation becomes

$$
-\frac{1}{m}-\frac{1}{n}+\frac{1}{r}=0
$$

and if $r=1$, the general formula $n=\frac{m}{m-1}$ is derived. Between $i: 1: 1(I)$ and $1: i: 1(1-\bar{i})$ the values of $n$ are positive, as with the series of planes $i: 1-i: 1-i ; 6 c: \frac{6}{5} b: a ; 5: \frac{5}{4}: 1 ; 4: \frac{4}{3}: 1 ; 3: \frac{3}{2}: 1$; $2: 2: 1 ; \frac{3}{2}: 3: 1$, etc., $1: i: 1$. Between $1: i: 1$ and $\frac{1}{2}$ the values of $n$ are negative, that is, are measured on the back half of the axis $b$; as, for example, $\frac{4}{5}:-4: 1 ; \frac{3}{4}:-3: 1 ; \frac{2}{3}:-2: 1 ; \frac{1}{2}:$ $-1: 1$. As the zone continues on from $\frac{1}{2}:-1: 1$ to $1:-1: \pm i\left(1-\frac{v}{)}\right)$, and $i:-1:-1(I)$, the unit axis is changed, making $n=-1$. The zone equation then becomes $r=\frac{-m}{m-1}$, the values of $r$ being positive between $\frac{1}{2}:-1: 1$ and $1:-1: \pm i$, and negative between $1:-1: \pm i$ and $i:-1:-1$.
 The successive planes are $\frac{2}{3}:-1: 2 ; \frac{8}{4}:-1: 3$;
 Both figures 233 and 234 are illustrations of this zone.

If the student will select a variety of examples of zones from the figures in the descriptive part of this work, and will apply the zone equation as given above to them, paying special attention to the signs of the parameters of each plane, he will soon find that the apparent difficulties of the subject disappear.

ExHibition of the Zone-relations of different planes by means of methods of PROJECTION.

The relations of the different planes of a crystal are to some extent exhi- . bited graphically in such figures às have been already given. Other methods, however, are used which have special advantages. The two most important are briefly mentioned here.

1. Quenstedt's method of projection.-In this method the planes of a crystal are projected upon a horizontal plane, usually that of the base $(O)$. Every plane is regarded as passing throngh the unit-length of the axis which is taken as the vertical; these planes consequently appear as straight lines intersecting each other on the plane of projection.

The following are examples. In f. 235, of galenite, there are present the planes of the cube, octahedron, dodecahedron, and tetragonal trisoctahedron $\frac{3}{2}-\frac{3}{2}$. In the projection (f. 236) the plane of the paper is taken
 as that of the cubic plane, the two equal lateral axes $(a)$ are shown in the dotted lines, and the vertical axis is perpendicular to the plane of the paper at their point of intersection. Any arbitrary length of the lateral axes, as $c a$, is taken as the unit. One of the cubic planes coincides with the plane of the paper, and the others, since they are supposed to pass through the unit point of the vertical axis, coincide with the projections of the lateral axes, and are marked $H, H$.

The octahedral planes (1) appcar as lines connecting the unit lengths of the equal lateral axes; of the dodecahedral planes, four pass each through
the extremity of one lateral axis, and parallel to the other, and four others are diagonal lines passing through the centre; they are marked $i$ in the figure. The other planes, $\frac{3}{2}-\frac{3}{2}$, when passing through the unit point of the vertical axis, are represented by the symbols $1: \frac{2}{8}: 1$, and $1: 1: \frac{2}{8}$, and $1: \frac{3}{2}: \frac{3}{3}$, in the first quadrant, and similarly in the other three.


The projection of the first of these planes is the line joining the points $x$ ( $c x=\frac{2}{8}$ of $c a^{1}$ ) and $a^{2}$; that of the second plane is the line joining the points $a^{1}$ and $y\left(c y=\frac{2}{8}\right.$ of $\left.c a^{2}\right)$; that of the third plane is the line joining the points $z^{1}$ and $z^{2}\left(c z^{1}=c z=\frac{3}{2}\right.$ of $\left.c a\right)$. The same method is followed in the other quadrants, the twelve lines, lightly drawn, in the figure are the projections
 of the twelve corresponding planes of the form $\frac{3}{2}-\frac{3}{2}$.
Fig. 237, 238, give another example (topaz) from the orthorhombic system. The dotted lines, as before (f. 238), show the lateral axes on which the relative unit lengths of $\bar{b}$ and $\check{a}$ belonging to this species have been marked off ( $\bar{b}=1.892, \check{u}=1$ ). The four lines passing through these unit points, $a$ and $b$, are the projections of the unit octahedron 1 . The unit prism, $I$, is projected in lines parallel to these, and passing through the centre. The prism $i-2$ also passes through the centre, but the direction is that of a line joining the unit length of the axis $\bar{b}$ with two times that of $\tilde{\ddot{a}}$. The symbol of the octahedron $\frac{3}{2}\left(=\frac{7}{2} c: b: a\right)$, becomes, on supposing the plane to pass through the unit point of the vertical axis $c: \frac{2}{3} b: \frac{2}{3} a$, and it is consequently projected in the lines
joining the points $t\left(c t=\frac{2}{8}\right.$ of $\left.c b\right)$, and $s\left(c s=\frac{2}{8}\right.$ of $\left.c a\right)$. The symbol of the plane $\frac{3}{2}{ }^{2}$ ( $=\frac{3}{2} c: b: 2 a$ ) becomes, on the same condition, $c: \frac{2}{8} b: \frac{4}{3} a$, and its projection lines consequently connect the points $t\left(c t=\frac{3}{8}\right.$ of $c b$ ) and $u$ (cu $=\frac{4}{3}$ of $c a$ ). The same method is followed in the other systems; in the hexagonal there are on the plane of projection three equal lateral axes cutting each other at angles of $60^{\circ}$.


It will be seen from these examples that planes in a zone all pass through the same point of intersection ; as in f. 234, $O, \frac{3}{2}-\frac{3}{2}, 1, i\left(a^{2}\right)$, and, f. 237, $I, i-\frac{\Sigma}{2}, i-\check{\imath}(c)$; this is also true mathematically of the planes $0,1, \frac{3}{2}$, $I$, whose projections are parallel. This principle, which follows immediately from the fact stated above that planes in a zone have a cominon ratio for two of the axes, is very important. If a given plane lie in two zones its projection must necessarily pass through the two points of intersections which belong to each of these respectively, and consequently its position is determined. The plane on f .237 which has no written syinbol for instance, lying in the zone with $\frac{3}{2}$ and $\frac{3}{2}$, and the zone with 1 and $\frac{3}{3}-2$, must, when projected, pass through the intersection point (f. 238) $s$ of the former zone, and also throngh $v$ that of the second zone. The plane itself, then, is one which meets the vertical axis at its unit length, the axis $b$ obviously at an infinite distance, and the axis $a$ at a distance $\frac{2}{3}$ of its unit length; hence, the symbol is $c: \infty b: \frac{2}{3} a$, or $\frac{3}{2} c: \infty b: a\left(\frac{3}{2}-\bar{i}\right)$ in the form it is usually written. In many cases the ratios of the lateral axes are obvious at sight, as here; in every case, however, the position of the zonal point, and of the two points of intersection on the axes, admits of exact determination by a series of simple equations.

These equations it is unnecessary to add here; reference for them may be made to Quenstedt's Crystallography, or that of Klein, mentioned on p.59. This method is of so general use and of so easy application that every student should be familiar with it. Its advantages are that it leads to a clearer comprehension of the relations of the different forms, showing immediately all the zones in which they lie, and in many cases-without the
use of equations-suffices to determine the symbols of au unknown plane and that more simply than by the use of the zonal equation. The general principles contained in the method have been made by its proposer (Quenstedt) the basis of an ingenions and philosophical system of Crystallogra pny (Grundriss der bestimmenden und rechnenden Kirystallographie von Hir. Aug. Quenstedt, Tübingen, 1873).
2. Spherical projection of Neumann and Miller.-In this snbject, as viewed by Miller, a crystal is situated within a sphere so that the centres of the two coincide. If now perpendiculars, or normals, be drawn from this centre to each plene, and be produced, they will meet the surface of the sphere, and these normal points will determine the position of each plane. If, then, this sphere is regarded as projected upon a horizontal plane it will appear as a circle, and the varions normal points will occupy each its proper position on or within this circle. This will be made more clear by an example. If the crystal (f. 237) be supposed to occupy the centre of a sphere, and if the terminal plane coincide with the plane of the paper, a normal to the plane $O$ will meet the sphere of projection at the central point (f. 239); the planes $i-\check{\check{L}}$ at the points indicated, and so of the other planes $1, \frac{3}{2}, i-z$, etc.

Two principles here are of fundamental importance: 1st, all planes of a zone have their normals in the same great circle, as $i-\check{\imath}, \frac{3}{2}, \frac{3}{2}-\bar{\imath}$, etc.; and $2 d$, the angles between these normal points are the supplements of the angles between the actual planes. These having been stated, it will be clear at once that the calculation of the angles between different planes, i.e., their normals, becomes merely a matter of solving a series of spherical triangles in which some parts are given and others obtained by calculation. Upon this basis a system of crystallography was constructed by Miller in 1839, which, as further developed by Grailich, Schranf, von Lang and Maskelyne, has every advantage over that of Nammann in the matter of facility of calculation as in some other even more important respects.

[^6]normal-point of $i-$ c. The lines drawn between $i-2,0$, and $i-2$ (behind), and $I, O, I$ (behind) represent the zones of the $m-\frac{2}{2}$ and $m$ pyramids respectively. The position of the normalpoints of a dome or pyramid upon its respective zonal line (great circle) is formed by laying off from the centre a distance equal to the tangent of half the supplement angle of the given plane on $O$, taking the radius as unity. For example, $O \wedge \frac{3}{2}-\bar{\imath}=126^{\circ} 27^{\prime}$, hence the position of the required normal-point will be about $\frac{1}{2}(.5046)$ of the radins measured from 0 .

It is in general necessary to determine in this way the normal-points of but very few of the planes, since those of the others are given by the zonal connection between the planes. Thus in this case, having determined in the way explained the positions of the points $i-\check{\imath}, i-\overline{2}$, $I$, and $\frac{3}{2}-\bar{i}$, no further calculation is needed; the point of intersection of the great circle joining $i-\bar{\imath}$. $\frac{3}{2}-\bar{\imath}$, and $i-\check{\imath}$, and that joining $I, O, I$, is the normal-point of $\frac{3}{2}$; also the point of intersection of the great circle $i-\frac{2}{2}, \frac{3}{2}-\bar{\imath}, i-\tilde{2}$ with $I, O, I$, is the normal-point of 1 , and with $i-\frac{2}{2}, O, i-\frac{2}{2}$ that of $\frac{3}{2}-2$.

The method explained is the same for all the orthometric systems; for the clinometric systems the same principle is made use of, though the application is not quite so simple, since the basal plane does not fall at the centre of the circle.

In the system of Miller the general form of the symbol is $l k l l$, in which $h, k$, and $l$ are always whole numbers, and, the reciprocals of Naumann's symbols. To translate the Jatter into the former it is only necessary to take the reciprocals and reduce the result to three whole numbers and write them in the proper order. In general, for $m-n(m c: n b: a$ ), $\hbar: k: l=m n: m: n$, the latter expression being written in its simplest form, and, if necessary, fractional forms must be reduced to whole numbers by multiplication. Conversely, from $l k l$ is obtained $m=\frac{h}{l}, n=\frac{h}{k}$, and hence, $\frac{h}{l}-\frac{h}{k}=m-n$. This applies to all the sys. tems except the hexagonal, where a special process is required. See Appendix (p. 441).

## Methods of Calcolation.

In mathematical crystallography there are three problems requiring solution: 1st. The determination of the elements of the crystallization of a species, that is, the lengths and mutual inclination of the axes; 2 d , The determination of the mutual interfacial angles of like or unlike known planes; and 3d, The determination of the symbols, that is, values of the parameters $m$ and $n$ for unknown planes.

This whole subject has been exhaustively discussed by Naumann in his several works on crystallography. (For titles, see p. iv.) The long series of formulas deduced by him cover alnost every case which can arise. In the present place the matter is treated briefly, since for all ordinary problems in crystallography the amount of mathematics required is very small. This is especially true in view of the fact that a large part of unknown planes can be determined by the zonal equation already given. When complicated problems do arise, the me hods of spherical trigonometry (based on the spherical projection of Miller) offer, in the opinion of most crystallographers, the simplest and shortest mode of solution. It is believed that the student who has mastered the elements of the subject, after the method of Naumann here followed, will, if he desire to go furtber, find it to his advantage to turn to the system of Miller, referred to on p. 58 (See also Appendix.) The formulas given under the different systems in the following pages are mostly those of Naumann, and it has been deemed desirable to explain at length, in most cases, the methods by which these formulas are deduced. If the student will follow these explanations through, he will find himself in a position to solve more difficult problems involving similar methods. Spherical triangles are employed in most cases, as early used by Hausmann (1813), by Naumann (1829), and others; and carefully explained by Von Kobell in 1867 (Zur Berechnung der Krystallformen). The same methods have been elaborated by Klein (Einleitung in die Krystallberechnung, Stuttgart, 1875).

THE RATIO OF THE TANGENTS IN RECTANGULAR ZONES.
Tangent principie.-In any rectangular zone of planes, that is, a zone lying between two planes at right angles to each other, one of them being a diametral plane, the tangents of the supplement angles made with this
diametral plane are proportional to the lengths of the axis correspouding to it.

Examples of rectangular zones are afforded by the zones between $i \cdot i$ and $i-i$, also $I$ and $O$, f. 130, and $I$ and $O$, in.f. 208; stili again between $I$ and $O$, in f. 167; $I$ and $O$, also $i-2$ and $O$, inf. 150. In f. 217, the zone between $i-i$ and $i-i$, and $O$ and $i-i$, as also the zones between $i-i$ and any one of the orthodomes, are rectangular zones, but not the zones between the basal and vertical planes (except $i-i$ ), nor those between $i-i$ and a clinodome.

The truth of the above law is evident from the accompanying figures.

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241
 If the angles between the planes $e^{1}, e^{2}, e^{3}(f .240)$ and the basal plane $O$ are given, their supplements are the angles with the basal diametral section $a^{1}, a^{2}, a^{3}$, respectively (f. 241). The tangents of these angles are the respective lengths of the vertical axis, corresponding to each plane, as seen in the successive triangles. In each case we have $b \tan a=c$, and hence, $\tan a^{1}: \tan$ $a^{2}: \tan a^{3}=c^{1}: c^{2}: c^{3}$.

By the law stated on p. 10 , the ratio of the axes must have some simple numerical value. In other words, if $c^{2}$ be taken as the unit, $c^{2}$ and $c^{3}$ must bear some simple ratio to it (denoted generally by $m$ ). In general, if $a^{1}$, $a^{2}, a^{3}$ are the supplement angles of three planes of a vertical zone upon a basal plane, then, $\tan a^{1}: \tan a^{2}: \tan a^{3}=m^{1} c: m^{2} c: m^{\circ} c=m^{1}: m^{2}: m^{3}$.
This is true as well for the pyramidal planes $p^{1}, p^{2}, p^{3}$, and the domes $d^{1}, d^{2}, d^{3}$ (f. 240). This principle is most commonly applied to a vertical zone, where the angles on the basal plane are known, and the value of $m$ for each is required; it applies, however, in the same way, to any rectangular zone.

For a prismatic zone, if the supplement angles on $i-\check{\imath}$ are given $=\gamma^{1}, \gamma^{2}$, etc., then,

$$
\tan \gamma^{1}: \tan \gamma^{2}: \tan \gamma^{3}=b^{1}: b^{2}: b^{3}=n^{1}: n^{2}: n^{3} .
$$


#### Abstract

These relations may perhaps be made more clear by a little further explanation. Suppose a plane to pass through the vertical axis at right angles to the given zone $0, e^{1}, e^{2}, e^{3}$, and intersecting it in the dotted line (see also f. 241). A similar section may be made with the planes $d^{1}, d^{2}, d^{3}$, or with $p^{1}, p^{2}, p^{3}$. From the section (f. 241), the relation of the vertical axes to the tangents of the basal angles is at once obvious. It will be seen here that $a^{1}, a^{2}$, etc., are not only the supplements of the interfacial angles measured on $O$, but are also equal to the angles measured on $i-\breve{i}$ diminished by $90^{\circ}$, and this is true in general. It will be also seen that the angles $a^{1}, a^{2}$, etc., may be obtained from the angles of the planes measured on each other. Thus, given $e^{1} \wedge 0=180^{\circ}-a^{1}$, and given $e^{1} \wedge e^{2}$, obviously $a^{2}$ (sup-


 plement of $\left.e^{2} \wedge 0\right)=a^{1}+\left(180^{\circ}-e^{1} \wedge e^{2}\right)$.
## USE OF SPHERICAL TRIGONOMETRY.

The use of a spherical triangle often simplifies very much the operation
of calculating the various angles and axial ratios. The following example will exemplify the principle involved. Fig. 242 represents a square octahedron of zircoir. If we take the front solid angle of the octahedron as a centre, and from it imagine three arcs to be described with any radius--one on the octahedral plane $B A$, another on the basal section $C A$, and a third on the diametral section $C B$, it is evident that a spherical triangle will be formed. In other words, the point $a$ is imagined to be the centre of a sphere and the triangle $A B C$ is that
 portion of its surface included between the three planes in question.

In this triangle (f. 243) the successive parts are as follows:
$C=$ the angle between the basal and vertical diametral sections; here $90^{\circ}$.
$a=$ the inclination of the vertical edge on the lateral axis.
$B=$ the semi-vertical angle of the octahedron $\left(=\frac{1}{2} X\right)$.
$h$ (the liypothenuse) $=$ the plane angle of the octahedral face.
$A=$ the semi-basal angle ( $=\frac{1}{2} Z$ ).
$b=$ the inclination of the basal edge on the lateral axis.
In the case given, $b=45^{\circ}$, since in this, the tetragonal system, the lateral axes are equal and the basal edge makes an angle of $45^{\circ}$ with each. Now if either $A$ or $B$ (that is, $X$ or $Z$ ) is given by measurement, two parte in the triangle will be known and the others can be red lily calculated as they may be required. Other examples will be found in the pages which follow.

In the majority of cases the spherical triangles obtained in the manner described are right-angled, and the problems resolve themselves into the solution of right-angled spherical triangles. In performing these operations practically, the student may be assisted by the following graphic method (used by Prof. Cooke, of Harvard University). It is based upon Napier's rules, which are familiar to every student:

In a right-angled spherical triangle the sine of any part is equal to the product of the cosines of the opposite parts, or the product of the tangents of the adjacent parts. Here it is to be remembered that for the two angles and hypothenuse the complements are to be taken.

The problems are represented graphically as follows: In the case given, suppose that the basal angle ( $Z$ ) on the given octahedron has been measured and found to be $84^{\circ} 19^{\prime} 46^{\prime \prime}$, that is, the angle $A=\frac{1}{2} Z=42^{\circ} 9^{\prime} 53^{\prime \prime}$, and hence $90^{\circ}-A=47^{\circ} 50^{\prime} 7^{\prime \prime}$. Then the parts of the triangle may be written, commencing with $C$,

|  | $90^{\circ}(C)$ | $a$ |  |
| :---: | :---: | :---: | :---: |
|  | $\left(90^{\circ}-A\right)$ | $\left(90^{\circ}-\hbar\right)$. | $\left(90^{\circ}-B\right)$ |

If. $B$ is required, we have (for zircon) $\sin \left(90^{\circ}-B\right)=\cos 45^{\circ} \times \cos 47^{\circ} 50^{\prime} 7^{\prime}$;
whence
and the vertical angle $(X)$ is
Also,
$B=61^{\circ} 39^{\prime} 47^{\prime \prime}$,
$123^{\circ} 19^{\prime} 34^{\prime \prime}$.
$B=61^{\circ} 39^{\prime} 47^{\prime \prime}$,
$123^{\circ} 19^{\prime} 34^{\prime \prime}$.
$\sin 45^{\circ}=\tan a \times \tan 47^{\circ} 50^{\prime} 7^{\prime \prime}$, $\tan a=0.640373=\dot{c}$, the vertical axis.

For convenience, some of the more important formulas for the solution of spherical triangles are here added.

In spherical right triangles $C=90^{\circ}$.

$$
\begin{array}{ll}
\operatorname{Sin} A=\frac{\sin a}{\sin h} & \sin B=\frac{\sin b}{\sin h} \\
\operatorname{Cos} A=\frac{\tan b}{\tan h} & \cos B=\frac{\tan a}{\tan h} \\
\operatorname{Tan} A=\frac{\tan a}{\sin b} & \tan B=\frac{\tan b}{\sin a} \\
\operatorname{Sin} A=\frac{\cos B}{\cos b} & \sin B=\frac{\cos A}{\cos a} \\
\begin{array}{ll}
\cos h & =\cos a \cos b \\
\cos h & =\cot A \cot B
\end{array}
\end{array}
$$

In oblique-angled spherical triangles:
(1) $\sin A: \sin B=\sin a: \sin b$;
(2) $\operatorname{Cos} a=\cos b \cos c+\sin b \sin c \cos A$;
(3) $\operatorname{Cot} b \sin c=\cos c \cos A+\sin A \cot B$;
(4) $\operatorname{Cos} A=-\cos B \cos C+\sin B \sin C \cos a$.
-In calculation it is often more convenient to use, instead of the latter formulas, thoss especially arranged for logarithms, which will be found in any of the many books devoted to mathematical formulas.

Cosine formula.-General equation for the inclination of two planes in the orthometric systems.

Representing the parameters of any plane by $c: b: a$, and also of any other plane by $c^{\prime}: b^{\prime}: a^{\prime}$, and placing $W$ for the supplement of their mutual inclination,

$$
\operatorname{Cos} W=-\sqrt{\frac{a a^{\prime} b b^{\prime}+c c^{\prime} a a^{\prime}+b b^{\prime} c c^{\prime}}{\left(a^{2} b^{2}+c^{2} a^{2}+b^{2} c^{2}\right) \sqrt{ }\left(a^{\prime 2} b^{\prime 2}+c^{\prime 2} a^{\prime 2}+b^{\prime 2} c^{\prime 2}\right)}}
$$

In using this equation, the actual values of the parameters are to be substituted for the letters. For the planes $m-n, m^{\prime}-n^{\prime}$, in the same octant, in which the parameters would be $m c: n b: a$, and $m^{\prime} c: n^{\prime} b: a$,

$$
\begin{aligned}
& m c, n b, a \text { are substituted severally for } c, b, a \text {. } \\
& m^{\prime} c, n^{\prime} b, a
\end{aligned}
$$

## I. Isometrio System.

The equality of the axes in the Isometric system makes it unnecessary to consider them in the calculations. The most commonly occurring problems are the determination of the symbuls in the various forms, $i-n, m$, $m-m, m-n$ (f. 51, 54, 65, 69). These cases will be considered in succession. In all but the last, but a single measurement is necessary.

1. Form in, tetrahexahedron.-The edges are of two kinds ( p .18 ), as $A$ and $C^{\prime}$ in f. 244; a measurement of either is sufficient to determine the value of $n$. (a) Given the angle of the edge A. Suppose a plane tc
pass through the edge $A$ and the adjoining axis, $a c$, also a second plane through the two lateral axes, and imagine a spherical triangle constructed, as explained on p. 61. This triangle (see f. 244a) is right angled at $C$, and the other angles are $\frac{1}{2} A$, (half the measured angle of the crystal) and $45^{\circ}$, respectively. Hence, if $\nu$ is the inclination of the plane on the lateral axis, $a c$,

$$
\begin{aligned}
& \cos \nu=\cos \frac{1}{2} A \sqrt{2} \\
& \quad \text { and } \tan \nu=n a=n .
\end{aligned}
$$

(b) Suppose the angle of the edge $C$ to be given. In the plane triangle $(a b c)$ of the section in $f .244, \frac{1}{2} \vec{C}+$
 $45^{\circ}+\nu=180^{\circ}$, or $\nu=135^{\circ}-\frac{1}{2} C$, and, as before, $\tan \nu=n$. If the angle of two opposite planes, meeting at the extremity of an axis, were given, half this angle would be the angle $\nu$. For a series of tetrahexahedrons the tangent law may be applied, since they form a zone between two cubic planes; the dodecahedron falls in this zone, being a special case of the tetrahexahedron where $n=1$. The angle between a plane $i-n$ and the adjoining cubic face $(H)$ is equal to $\nu+90^{\circ}$, hence, $\cot H=n$.
2. Form $m$, trigonal trisoctahedron.-The edges are of two kinds, $A$ and $B$. (a) If the angle over $B$ is given, suppose a diagonal plane to pass through the vertical axis and the edge $A$, ineeting the planes, as indicated in the figure. A right-angled plane triangle is formed, of which the basal angle is equal to $\frac{1}{2} B$, and the base is the diagonal line $x$. Then $x \tan \frac{1}{2} B=$ the vertical side of the triangle $(m a)$, but $x=\sqrt{\frac{1}{2}}$ when $a=1$, whence $\tan \frac{1}{2} B \sqrt{\frac{1}{2}}=m a$ or $m$. (b) If the given angle is that of the edge $A$, place a spherical triangle ( $m a$ ), as indicated in the figure. In this triangle $C=90^{\circ}$ (for the diagonal plane is perpendicular to the plane $m$ ), and the other angles are respectively $\frac{1}{2} A$ (half the measured angle) and $60^{\circ}$; hence, the side opposite $\frac{1}{2} A$ ( $=$ the angle $\rho$ ) is obtained. Further, the angle of the two dotted diagonals (the octahedral and dodecahedral axes) is $35^{\circ} 16^{\prime}$ (p.16), whence, $\frac{1}{2} B=144^{\circ} 44^{\prime}-\rho$, and, as before,
 $\tan \frac{1}{2} B \sqrt{\frac{1}{2}}=m$. See further the following case. The general equations are thus:

$$
\begin{gather*}
\tan \frac{1}{2} B \sqrt{\frac{1}{2}}=m  \tag{a}\\
\cos \rho=2 \cos \frac{1}{2} A \sqrt{\frac{1}{3}} ; \frac{1}{2} B=144^{\circ} 44^{\prime}-\rho \tag{b}
\end{gather*}
$$

3. Form $m \cdot m$, tetragonal trisoctahedron.-Suppose (a) that the angle of the edge $B$ is given. In the spherical triangle 1 , in $f .246, C=90^{\circ}$, and
each of the other angles equals $\frac{1}{2} B$. Hence, one of the equal sides (= angle $\nu$ ) is obtained, and $\tan \nu=m$. (b) If the angle $C^{\prime}$ is given,
 the triangle 2 , in f. 246 , is employed here one angle is $=90^{\circ}$, a second $=60^{\circ}$, and the third $=\frac{1}{2} C$, half the measured angle of the edge $C$. The side of the triangle $=$ the angle $\rho$ is calculated, and, as in the preceding case, $\zeta \equiv 144^{\circ} 44^{\prime}-\rho$, then $m+1$ $=\tan \zeta \sqrt{2}$.
The planes $m-m, 1, m$, form a zone between the cubic and dodecahedral planes as f. 461, p. 244 , to which the tangent law may be often conveniently applied. The form $m$ passes into the octahedron 1 when $m=1$, and when $m$ is less than unity it becomes $m-m$, as explained on p. 17.
Since these planes form a rectangular zone the tangent of the supplement angles between them and a cubic plane are proportional to the values of $m$ for the given forms; only by applying this principle for $m-m$, the index $\frac{1}{m}\left(=\frac{1}{m}: 1: 1\right)$ will be obtained, which is equivalent to $m-m$ ( $=1: m: m$ ).

The general equations for the form $m-m$ are:

$$
\begin{gather*}
\cos \nu=\cot \frac{1}{2} B ; \tan \nu=m  \tag{a}\\
\cos \rho=\cot \frac{1}{2} C \sqrt{\frac{1}{8}} ; \zeta=144^{\circ} \cdot 44^{\prime}-\rho ; \tan \zeta \sqrt{2}=m+1
\end{gather*}
$$


4. Form $m-n$, hexoctahedron.-The edges of the hexoctahedron are of three kinds, $A, B, O$ (f.247), and two measurements are, in general, needed in order to deduce the ralues of $m$ and $n$.
(a) Given $A$ and $B$. In the oblique-angled spherical triangle I (f. 247), the three angles are $\frac{1}{2} A, \frac{1}{2} B$, and $45^{\circ}$. In this triangle, the side opposite $\frac{1}{2} A(=$ angle $\nu)$ is calculated, and from it are obtained the values of $m$ and $n$, as follows:

$$
\cos \nu=\frac{\cos \frac{1}{2} A \sqrt{2}+\cos \frac{1}{2} B}{\sin \frac{1}{2} B} ; \tan \frac{1}{2} B \sin \nu=m ; \tan \nu=n .
$$

(b) Given $A$ and $C$. In the oblique-angled triangle II (f. 247), the three angles are equal respectively to $\frac{1}{2} A, \frac{1}{2} C$, and $60^{\circ}$ The side opposite $\frac{1}{2} A$ (= angle $\rho$ ) is calculated. But the angle between the diagonals, that is, the octahedral and dodecahedral axes, is $35^{\circ} 16^{\prime}$, and the third angle of the triangle is $\zeta$, the inclination of the edge $C$ on the dodecahedral axis ;
hence, $\}=144^{\circ} 44^{\prime}-\rho$. Again, in the right-angled triangle III (f. 247), one angle $=\frac{1}{2} C \gamma$, and the adjaceut side $=\zeta$, whence the other side, $\delta$ (the inclination of the edge $B$ on the dodecahedral axis), is obtained ; $\nu=135^{\circ}-\delta$, and from this, as above, and from the angle $\rho$, are dednced the values of $n$ and $n$. The formulas are:

$$
\begin{gathered}
\cos \rho=\frac{2 \cos \frac{1}{2} A+\cos \frac{1}{2} C^{\gamma}}{\sin \frac{1}{2} C^{\gamma} \sqrt{3}} ; \zeta=144^{\circ} 44^{\prime}-\rho ; \tan \delta=\sin \zeta \tan \frac{1}{2} C \\
\nu=135^{\circ}-\delta ; \tan \nu=n ; \frac{n \sqrt{2}}{n+1} \tan \zeta=r \omega .
\end{gathered}
$$

(c) Given $B$ and $C$. IL the right-angled triangle, III (f. 247), the twc, angles are given, equal respectively to $\frac{1}{2} B$ and $\frac{1}{2} C$. From the triangle is deduced the side opposite $\frac{1}{2} C$ ( $=$ angle $\delta$ defined before), and from it is obtained $\nu$, and from $\nu$ and $\frac{1}{2} B$, the values of $m$ and $n$, as in the first case. The formulas are:

$$
\cos \delta=\frac{\cos \frac{1}{2} C}{\sin \frac{1}{2} B} ; \nu=135^{\circ}-\delta ; \tan \nu=n ; \tan \frac{1}{2} B \sin \nu=m .
$$

If, instead of $m-n$, the form is $m-\frac{m}{m-1}$, only one measurement is needed, and the process is simplified.

When the angles of any plane $m-n$ on two cubic planes are given, their supplements will be the angles of the plane upon the corresponding diametral sections, and from them the values of $m-n$ may be readily caleulated. Thus (in $\mathbf{f} .248$ ), the angles of a given plane on a cubic plane at $a^{2}$ will be the supplement of its angle upon the section $a^{1} a^{3}$, that is, the angle $B$ in the spherical triangle; similarly, the angle of a cubic plane at $a^{3}$ will be the supplement of its angle on the section $a^{1} a^{2}$, the angle $A$ in the spherical triangle. In this same triangle $C=90^{\circ}$. Hence, the sides opposite $A$ and $B$, that is, the inclinations of the two edges on the adjacent axis, may be calculated, and this axis being equal to unity, their tangents will give the corresponding lengths of the other axes. These lengtlis may not be the values of $m$ and $n$ in the form in which the symbol is generally written, where the unit axis is always the shortest,
 but the latter are inmediately deducible. For example, if the angles here mentioned for the plane numbered 4 (in f. 247) had been measured, the values of the axes obtained by calculation, when the front axis is the mit, would be $\frac{1}{3}$ and $\frac{1}{2}$ respectively, and the symbol, hence, $\frac{1}{8}: \frac{1}{2}: 1$, which is equivalent to $1: \frac{3}{2}: 3$, or $m-n=3-\frac{3}{2}$ for the general form.

Hemihedral forms.-For each hemihedral form the formulas are identical with those already given for the corresponding holohedral, so far as the edges of the two are the same. For example, in comparing f. 69 and f. 87 it is seen that the edges $A$ and $C^{C}$ are the same in both, while $B$ of the holohedral form differs from $B^{\prime}$ of the hemihedral. The formulas re-
quired to cover these additional cases are given below, they are obtained in a manner similar to those in the preceding pages.

Form $\frac{1}{2}(m)$, f. 85. Given $B^{\prime}$.

$$
\cos \epsilon=2 \cos \frac{1}{2} B^{\prime} \sqrt{\frac{1}{8}} ; \zeta=35^{\circ} 16^{\prime}+\epsilon ; \tan \zeta \sqrt{\frac{1}{2}}=m .
$$

Form $\frac{1}{2}(m-m)$, f. 81. Given $B^{\prime}$.

$$
\tan \frac{1}{2} B^{\prime} \sqrt{2}=m
$$

Form $\frac{1}{2}(m-n)$, f. 87. (a) Given $A^{\prime}$ and $B^{\prime}$.
$\cos a=\frac{\cos \frac{1}{2} B^{\prime}}{\sin \frac{1}{2} A^{\prime}} ; \quad \cos \beta=\frac{\cos \frac{1}{2} A^{\prime}}{\sin \frac{1}{2} B^{\prime}} ; m=\frac{\sqrt{2}}{\cot a-\cot \beta} ; n=\frac{\sqrt{2}}{\cot a+\cot \beta_{0}}$.
(b) Given $B^{\prime}$ and $C^{\prime \prime}$.

$$
\begin{gathered}
\cos \epsilon=\frac{2 \cos \frac{1}{2} B^{\prime}+\cos \frac{1}{2} C^{\prime}}{\sin \frac{1}{2} C^{\prime} \sqrt{ } \overline{3}} ; \zeta=35^{\circ} 16^{\prime}+\epsilon ; \cot \delta=\tan \frac{1}{2} C^{\prime \prime} \sin \zeta . \\
\tan \left(\delta+45^{\circ}\right)=n ; \frac{n \sqrt{ } \overline{2}}{n+1} \tan \zeta=m .
\end{gathered}
$$

Form $\frac{1}{2}[i-n]$, f. 92. Given $A^{\prime \prime}$.

$$
\tan \frac{1}{2} A^{\prime \prime}=n
$$

Form $[m-n]$, f.100. (a) Given $A^{\prime \prime}$ and $B^{\prime \prime}$.

$$
\frac{\cos \frac{1}{2} A^{\prime \prime}}{\sin \frac{1}{2} B^{\prime \prime}}=\cos \nu ; \tan \nu=n ; \frac{n \cos \frac{1}{2} A^{\prime \prime}}{\cos \frac{1}{2} B^{\prime \prime}}=m .
$$

(b) Given $A^{\prime \prime}$ and $C^{\prime \prime}$

$$
\begin{aligned}
& 2 \cos \frac{1}{2} C^{\prime \prime} \sqrt{\frac{7}{8}}=\sin O ; \cos \theta=\frac{\cos O \sqrt{3}-\cos \frac{1}{2} A^{\prime \prime}}{\sin \frac{1}{2} A^{\prime \prime} \vee \overline{2}} \\
& \quad \tan \left(45^{\circ}+\theta\right)=m ; \sin \left(45^{\circ}+\theta\right) \tan \frac{1}{2} A^{\prime \prime}=n
\end{aligned}
$$

(c) Given $B^{\prime \prime}$ and $C^{\prime \prime}$.

$$
\begin{gathered}
2 \cos \frac{1}{2} C^{\prime \prime} \sqrt{\frac{1}{8}}=\sin O ; \cos \delta=\frac{\cos O \sqrt{3}-\cos \frac{1}{2} B^{\prime \prime}}{\sin \frac{1}{2} B^{\prime \prime} \sqrt{2}} \\
\tan \left(45^{\circ}+\delta\right)=n ; \sin \left(45^{\circ}+\delta\right) \tan \frac{1}{2} B^{\prime \prime}=m
\end{gathered}
$$

The varions combinations of holohedral and hemihedral forms which may nccur are unlimited, and it would be unwise to attempt here to show
the neethods of working them out. It is only necessary to remark that the solution can generally be readily obtained by the use of one or two spherical triangles in the way shown in the preceding cases.

The calculation of the interfacial angles between two known forms can often be performed by the furmulas already given, or by similar methods For the more general cases, reference must be made to the cosine formula, p. 62.

## Interfacial Angles.-I. Holohedral Forms.

The following are some of the angles among the more common of Isometric holohedral forms; adjacent planes are to be understood, unless it is stated otherwise. The angles $A, B, C$, above, are those over the edges so lettered in the figures referred to (see pp. 15-19), or over the corresponding edges in related forms:
$H \wedge H=90^{\circ}$, f. 38
$H \wedge 1=12516^{\prime}$, f. 40,41
$H \wedge i=135$, f. $43,45$.
$H \wedge i-\frac{3}{2}=14619$
$H \wedge i-2=15326$, f. 64
$H \wedge i-3=16134$
$H \wedge{ }^{\frac{4}{3}-\frac{4}{3}}=13319$
$H_{\wedge} \stackrel{\frac{3}{2}-\frac{3}{3}}{ }=13645$
$H \wedge 2-2=14444$, f. 55
$H \wedge 3-3=15446$
$H \wedge \frac{3}{2}, o v .1,=11514$
$H \wedge 2, \quad 6=10928$, f. 52
$H \wedge 3, \quad$ " $=10316$
$H \wedge 3-\frac{3}{2}=14318$, f. 70
$H \wedge 4-2=15048$
$H \wedge 5-\frac{5}{3}=14741$
$1 \wedge 1=10928$, f. 42
$1 \wedge 1$, top,$=7032$
$1 \wedge i=14444$, f. 47
$1 \wedge i-\frac{3}{2}=14311$
$1 \wedge i-2=14016$, f. 67
$1 \wedge i-3=13654$
$1 \wedge \frac{3}{2}-\frac{3}{2}=16841$
$1 \wedge 2-2=160^{\circ} 32^{\prime}$, f. 58
$1 \wedge 3 \cdot 3=15030$, f. 57
$1 \wedge \frac{3}{2}=16949$
$1 \wedge 2=16412, \mathrm{f} .53$
$1 \wedge 3=158$
$1 \wedge 3-\frac{3}{2}=15745$
$1 \wedge 4-2=15152$
$1 \wedge 5-\frac{5}{3}=15125$
$i \wedge i=120$ f. 45
$i \wedge i$, ov. top,$=90$
$i \wedge i-\frac{3}{2}=16742$
$i \wedge i-2=16134$, f. 68
$i \wedge i-3=15326$
$i \wedge 2-2=150$
$i \wedge 3-\frac{3}{2}=16054$
$i \wedge 3-3=14831$
$i \wedge 4-\frac{4}{s}=1666$
$i \wedge 5-\frac{5}{3}=16258 \frac{1}{2}$
$2-2 \wedge 2-2, B,=13149$, f. 54
$2-2 \wedge 2-2, C,=14627$
2-2 $\wedge 2-2$, ov. top. $=10928$
$3-3 \wedge 3-3, B,=14454$, f. 61
$3-3 \wedge 3-3, C,=12931$

$$
\begin{aligned}
& i-\frac{3}{2} \wedge i-\frac{3}{2}, A,=183^{\circ} 49^{\prime} \\
& i-\frac{3}{2} \wedge i-\frac{3}{2}, C,=15723 \\
& i-2 \wedge i-2, A,=1438 \text {, f. } 65 \\
& i-2 \wedge i-2, C,=1438 \\
& i-2 \wedge i-2, \text { ov. top }=12652 \\
& i-2 \wedge i-3=17152 \\
& i-2 \wedge 2-2=15554 \\
& i-3 \wedge i-3, A=1549 \text {, f. } 6 \text { к } \\
& i-3 \wedge i-3, C,=12652 \\
& 2 \wedge 2, A,=15244, \text { f. } 51 \\
& 2 \wedge 2, B,=1413 \frac{1}{2} \\
& 3 \wedge 3, A,=1428 \\
& 3 \wedge 3, B=15328 \frac{1}{2} \\
& 3-\frac{3}{2}, A,=15813, \mathrm{f}, 69 \\
& 3-\frac{3}{2}, B,=149 \\
& 3-\frac{3}{2}, C,=15813 \\
& 4-2, A,=16215 \\
& 4-2, B,=15447 \frac{1}{2} \\
& 4-2, C,=1443 \\
& 5-\frac{5}{3}, A,=15220 \\
& 5-\frac{5}{3}, B,=16032 \\
& 5-\frac{5}{3}, C,=15220
\end{aligned}
$$

## II. Hemikedral Forms.

The following are the angles for the corresponding hemihedral forms:

| $\wedge 1=70^{\circ} 32^{\prime}, \mathrm{f} .76,76 \mathrm{~A}$ | $3 \cdot 3 \wedge 3-3, C,=134^{\circ} \mathbf{2}^{\prime}$ | $i-3 \wedge i-3, C,=107^{\circ} 27 \frac{1^{\prime}}{}{ }^{\prime}$ |
| :---: | :---: | :---: |
| $\frac{3}{2} \wedge \frac{3}{2}, A,=16239 \frac{1}{2}$ | $3-\frac{3}{2} \wedge 3-\frac{3}{2}, A,=15813$, f. 87 | 4-2 $\wedge 4-2, A,=12815$ |
| $\frac{3}{2} \wedge \frac{3}{2}, B_{2}=8210$ | $3-\frac{3}{2} \wedge 3-\frac{3}{2}, B, \doteq 11055 \frac{1}{2}$ | 4-2 $\wedge$ 4-2, $B$, $=154$ 47 ${ }^{\text {2 }}$ |
| $2 \wedge 2, A$, $=15244$, f. 85 | $3-\frac{3}{2} \wedge 3-\frac{2}{2}, C,=15813$ | $4-2 \wedge 4-2, C,=13149$ |
| $2 \wedge 2, B,=90$ | $4-2 \wedge 4-2, A,=16215$ | $3-\frac{3}{2} \wedge 3-\frac{3}{2}, A,=11523$, f. 10 C |
| $3 \wedge 3, A,=1428$ | $4-2 \wedge 4-2, B,=12451$ | $3-\frac{3}{2} \wedge 3-\frac{3}{2}, B,=149$ |
| 3 $\wedge 3, B,=995$ | $4-2 \wedge 4-2, C,=1443$ | $3-\frac{3}{2} \wedge 3-\frac{3}{2}, C,=14147$ |
| ${ }^{\frac{3}{2}-\frac{3}{2}} \wedge$ ^ $\frac{3}{2}-\frac{3}{2}, B,=9322$ | $i-\frac{3}{2} \wedge i \cdot \frac{3}{2}, A,=11237$ | $5-\frac{5}{3} \wedge 5-\frac{5}{3}, A,=1193 \frac{1}{3}$ |
| $\frac{3}{2}-\frac{3}{2} \wedge \frac{3}{2}-\frac{3}{2}, C,=16015$ | $i \cdot \frac{3}{2} \wedge i \cdot \frac{3}{2}, \quad C,=11729$ | $5-\frac{6}{3} \wedge 5-\frac{5}{3}, B,=16032$ |
| $2-2 \wedge 2-2, B,=10928$, f. 81 | $i-2 \wedge i-2,4,=12652$, f. 92, 93 | $5-\frac{5}{3} \wedge 5-\frac{5}{3}, C^{\prime},=1315$ |
| $2.2 \wedge 2-2, C,=14626 \frac{1}{2}$ | $i-2 \wedge i-2, c^{\prime},=11335$ |  |
| $3.3 \wedge 3-3, B,=1247$ | $i-3 \wedge i-3, A,=1438$ |  |

In the forms $i-\frac{3}{2}, i-2$ (f. 92), $i-3, i-4, A$ is the angle at the longer edge, and $C$ that at either of the others.

## II.-Tetragonal System.

In the Totragonal system, as has been fully explained (p. 30), the iongth of the vertical axis is variable, and must be determined for each species. If the length of $\dot{c}$ is known, then it may be required to determine the symbols of certain planes by means of measured angles. These two problems are in a measure complementary to each other, and the same methods wili give a solution to either case. (For figures of the forms see pages 27 and 28.) The calculation of the interfacial angles can be performed by similar methods or by the cosine formula.

1. Form $m$.-The edges are of two kinds, pyramidal $X$, and basal $Z$. If either angle is known, the angle $a$, which is the inclination of the edge $X$ on the lateral axis, may be calculated by the spherical triangle, as in f. 242,243 . (Compare the explanation of this case, p. 62.) Obviously in the plane right-angled triangle formed by the two axes and the edge $X$, $\tan a=m \dot{c}$ (since $a=1$ ). If $c$ is known, then $m$ is determined; and, conversely, a value being assumed for $m$, in the special case, $\dot{c}$ is given by the calculation. The general formulas are :

$$
\cot \frac{1}{2} X=\sin a \text {, or } \tan \frac{1}{2} Z \sqrt{\frac{1}{2}}=\tan a \text {; then } \tan a=m c \text {. }
$$

2. Form $m-i$.-(a) Given the angle $Z, m c$ is found immediately; the
 solution is obvious, for in the section indicated by the dotted line (f. 249), $\frac{1}{2} Z=a$, and the tangent of this angle is equal to the vertical axis. (b) Given the angle $Y$. A spherical triangle placed as in f. 249, has one angle $=\frac{1}{2} Y$, a second $=45^{\circ}$, and the third $=90^{\circ}$, whence the side opposite $\frac{1}{2} Y$ is calculated, which is the complement of $a$.

The general formulas, which may serve to deduce the value of $m$, when $\dot{c}$ is given, or the converse, are :

$$
\cos \frac{1}{2} Y \sqrt{2}=\sin a, \text { or } \tan \frac{1}{2} Z=\tan a, \text { and } \tan a=m c .
$$

If a series of square octahedrons $m$, or $m-i$, occur in a vertical zone, their symbols may be calculated in both cases alike by the law of the tangents, the angles of the planes on $O$, or on $I$, or $i-i$, respectively, being given. (See p. 60.)
3. Form $i$-n.-For the angle of the edge $X$ (f. 109, p. 26), at the extremity of a lateral axis, $\tan \frac{1}{2} X=n$. From the angle of the other edge $Y$, we have $\frac{1}{2} X=135^{\circ}-\frac{1}{2} Y$; and hence, $\tan \left(135^{\circ}-\frac{1}{2} Y\right)=n$.
4. Form $m$-n.-The edges are of three kinds, $X, Y, Z(f .250)$, and two angles must be given in the general case to determine $m$ and $n$.
(a) Given $X$ and $Z$. A spherical triangle having its vertices on the edges $J$ and $Z$, and the lateral axis, as 1 , f. 250 , will have two of its angles equal to $\frac{1}{2} X, \frac{1}{2} Z$, respectively, and the third equal to $90^{\circ}$. The solution of this triangle gives the sides, viz., $a$ and $\nu$, the inclinations of the edges $X$ and

Z, respectively, on the lateral axis. The tangents of these angles give the values of $m$ and $n$. The formulas are as follows:

$$
\frac{\cos \frac{1}{2} Z}{\sin \frac{1}{2} X}=\cos a, \tan a=m c ; \frac{\cos \frac{1}{2} X}{\sin \frac{1}{2} Z}=\cos \nu, \tan \nu=n .
$$

(b) Given $Y$ and $Z$. In a second triangle placed as indicated (2, f. 250), two of the angles are $\frac{1}{2} Y$ and $\frac{1}{2} Z$ respectively, and the third is $90^{\circ}$. The solution of this second triangle gives $\delta$, the inclination of the edge $Z$ on the diagonal axis, from which, in the plane triangle we have $\nu=135^{\circ}-\delta$, and from $\nu$ is obtained $n$. Still again from the triangle 1 (f. 250), and its solution used in the preceding case, having given $Z$ and $\nu, a$ is obtained, and from it $m$; as by the following formulas:

$$
\begin{array}{r}
\frac{\cos \frac{1}{2} \Gamma}{\sin \frac{1}{2} Z}=\cos \delta, \nu=135^{\circ}-\delta, \tan \nu=n \\
\tan \frac{1}{2} Z \sin \nu=\tan a=m c
\end{array}
$$

(r) Given $X$ and $Y$. A third triangle, numbered 3 in the figure, has two of the angles equal to $\frac{1}{2} X$ and $\frac{1}{2} Y$ respertively, and the third is $45^{\circ}$. Solving this oblique-angled triangle, the angle of the inclination of the edge $Y$ on the vertical axis is obtained, and its complement is the angle $\epsilon$, the inclination of the edge $Y$ on the diagonal axis; from $\epsilon$ and $\frac{1}{2} Y$ are obtained, by triangle $2, \delta$, and thence, as above, $n$; and finally, from $X$ and $\nu$, is obtained $a$, and from that the value of $m$. The simplified formulas are as follows:

$$
\frac{\cos \frac{1}{2} Y \sqrt{2}}{\cos \frac{1}{2} X}=n-1 ; \sin a=n \cot \frac{1}{2} X, \tan a=m c
$$

Pyramids of the general symbol 1-n, $m-m$, etc., are especial cases of the preceding, the processes being for them, however, somewhat simplified. A single measurement is sufficient.

## III. Hexagonal System.

In the Hexagonal system there are three equal lateral axes (a) inter secting at angles of $60^{\circ}$, and a fourth vertical axis $(c)$ at right angles to the plane of the others. Taking $a=1$, there remains but one unknown quantity in the elements of a crystal, that is the length of $\dot{c}$, and a single measurement is sufficient to determine this. The relations of the three lateral axes have been explained on p. 32 .

The hexagonal system is closely allied to the tetragonal, and optically they are identical, as is shown beyond.

Schrauf refers all hexagonal forms to two lateral axes crossing at right
angles and a vertical axis, in order to show this relation. According to him, in this system, the axes are $c: a \sqrt{3}: a$; in the tetragonal they are $\dot{c}: a: a$. Miller's school, on the contrary, employ three equal axes, making equal angles with each other, and each normal to a face of the fundamental :hombohedron. In each of these methods a holohedral form, for instance a hexagonal pyramid, is considered as made up of two sets of forms, having different indices.

## A.-Holohedral Forms.

1. Form $m$ : hexagonal pyramid, first series.-Suppose a spherical triangle, inscribed in f. 148, p. 33, having its vertices upon the edges $X$ and $Z$, and the corresponding lateral axis respectively, similar to the triangle of f. 242. This will be a right-angled triangle.
(a) When the angle of the edge $X$ is given, then $\xi$, the inclination of the edge $X$ upon the adjoining lateral axis, is calculated :
$\sin \xi=\cot \frac{1}{2} X \sqrt{3}$, and $\tan \xi=m c$, or $=\dot{c}$, the vertical axis, when $m=1$.
(b) Given the angle $Z$.

$$
\tan \frac{1}{2} Z \sqrt{\bar{s}}=m c, \text { or }=\dot{c} \text { when } m=1 .
$$

2. Form m-2 : hexagonal pyramid, second series.-These pyramids bear the same relation to those of the $m$ series as the $m \cdot i$ octahedrons to $m$ octahedrons of the tetragonal system. (Compare f. 112, 146.) The methods of calculation are similar (f. 249.) The edges are of two kinds, vertical $Y$ and l,asal $Z$.
(a) Given the angle $Y$.

2 ens $\frac{1}{2} Y=\sin \frac{1}{2} Z$, and $\tan \frac{1}{2} Z=m c$, or $\dot{c}$ when $m=1$.
(b) Given the angle $Z$. Then simply

$$
\tan \frac{1}{2} Z=m c .
$$

3. Form $i-n$ : dihexagonal prism. -The vertical edges are of two kinds, axial $X$, and diagonal $Y$; the solution in either case is by means of a plane triangle, in a cross-section analogous to that of $f .146$.
(a) Giren $X$.
(b) Give: $Y$.

$$
\tan \frac{1}{2} X \sqrt{\frac{1}{8}}=\frac{n}{2-n} .
$$

$$
\tan \frac{1}{2} T \sqrt{3}=\frac{n+1}{n-1}
$$

4. Form $n-n$ : dihexagonal pyramid.-The edges (f. 251) are of three kinds, $X$ and $Y$ terminal, and $Z$ basal; measurements of two of these are required to give the values of $m$ and $n$; this is analogous to the calculation for the form $m-n$ in the preceding system.
(a) Given $X$ and $Z$. In a spherical triangle having its vertices on the edges $X$ and $Z$, and the adjoining lateral axis respectively, two angles are given. If $\nu=$ the inclination of the edge $Z$ upon the lateral axis (the side of the spherical triangle opposite the angle $\frac{1}{2} X$ ), then


$$
\cos \nu=\frac{\cos \frac{1}{2} X}{\sin \frac{1}{2} Z}, n-\frac{1}{2}=\tan \left(\nu-30^{\circ}\right) \sqrt{\frac{8}{4}} ; \tan \frac{1}{2} Z \sin \nu=m c .
$$

(b) Given $Y$ and $Z$. The right-angled spherical triangle has its vertices on the edges $Y$ and $Z$ and the diagonal axis. If $\delta=$ the inclination of the edge $Z$ upon this diagonal lateral axis, then:

$$
\cos \delta=\frac{\cos \frac{1}{2} Y}{\sin \frac{1}{2} Z} ; \text { but } n-\frac{1}{2}=\tan \left(120^{\circ}-\delta\right) \sqrt{\frac{3}{4}},
$$

also

$$
\left(150^{\circ}-\delta\right)=\nu ; \text { and, as before, } \tan \frac{1}{2} Z \sin \nu=m c
$$

(c) Given $X$ and $Y$. In the oblique-angled spherical triangle, with its vertices upon the edges $X$ and $Y$ and the vertical axis, the three angles are known, viz., $\frac{1}{2} X, \frac{1}{2} Y$, and $30^{\circ}$, hence :

$$
\frac{2-n}{n-1}=\frac{\cos \frac{1}{2} X \sqrt{3} .}{\cos \frac{1}{2} Y}
$$

Further, if $\xi=$ the angle of inclination of the edge $X$ upon a lateral axis, that is, the complement of the same edge upon the vertical axis (the side of the spherical triangle opposite the angle $\frac{1}{2} Y$ ),

$$
\sin \xi=n \frac{\sqrt{3}}{2-n} \cot \frac{1}{2} X, \text { and } \tan \xi=m c .
$$

If the pyramid $m-n$ takes the form $m-\frac{m}{m-1}$, as determined by its zonal relations, the calculations are simplified, since one unknown quantity only, $m$, has to be determined, and one measurement is sufficient.

## B.-Rhombohedral Division.

The relation of the rhombohedrons and scalenohedrons to the true hexagonal forms has been made clear in another place. The rhombohedron is the hemihedral form of the hexagonal pyramid $m$, and its symbol is writ-
ten $\frac{m}{2}$, or usually $m I 2$. The scalenohedron is the corresponding hemihe dral form of the twelve-sided pyramid, and its symbol is written $\frac{1}{2}(m-n)$ or $m^{\prime} l^{n^{n}}$. The latter symbol, proposed by Naumann, has reference to the rhombohedron whose lateral edge corresponds to the edge $Z$ of the given scalenohedron.

The formulas given by Naumann for reducing the symbol $\frac{1}{2}(m-n)$ to the form $m^{\prime} R^{n \prime}$ are as follows:

$$
m^{\prime}=\frac{m(2-n)}{n}, \text { and } n^{\prime}=\frac{n}{2-n},
$$

For the converse, to reduce $m^{\prime} R^{n \prime}$ to the form $\frac{1}{2}(m-n)$,

$$
m=m^{\prime} n^{\prime} \text { and } n=\frac{2 n^{\prime}}{n^{\prime}+1}
$$

1. Rhombohedrons, $m R$.-The methods of calculation are simple, and will be understood from f. 252. The edges are of
 two kinds, $X$ and $Z$, and their relation is such that the corresponding angles are the supplements of each other.

Given the angle of the edge $X$. A spherical triangle is placed, as indicated by $A B C$, in f. 252, with its vertices respectively on the edge $X$, the vertical axis, and the diagonal of the rhombohedral face. In this triangle $A=\frac{1}{2} X, B=60^{\circ}$, and $C=90^{\circ}$, but $\cos a=\frac{\cos A}{\sin B}=\frac{\cos \frac{1}{2} X}{\sin 60^{\circ}}$; here $a$ is the inclination of the diagonal line upon the vertical axis, that is, the complement of $a$, its inclination upon the basal section. Now in the plane triangle $a b c$, where $a c=$ the lateral axis $=1, a b=\sqrt{\frac{\overline{3}}{4}}$, hence, $\tan a \sqrt{\frac{8}{4}}=m c$, or $=\dot{c}$, the vertical axis of the rhombohedron, when $m=1$.

The general formulas are then :

$$
\sin a=\frac{\cos \frac{1}{2} X}{\sin 60^{\circ}}, \text { and } \tan a \sqrt{\frac{3}{4}}=m c
$$

Obviously, when the angle of $R$ (or $m R$ ) upon the basal plane $O$ can be measured, the supplement of this is the angle $a$. Similarly the angle $R \wedge 1$ $-90^{\circ}=a$.

In a series of rhombohedrons in a vertical zone, the tangent law can be advantageously applied. Attention must also be called to the zonal relations of certain + and - rhombohedrons, remarked on p. 36 ; these relations may be conveniently shown by means of Quenstedt's method of projection.
2. Scalenohedrons, $m R^{n}$.-As seen in $\mathrm{f} .171, \mathrm{p} .37$, the edges are of three kinds, $X, Y, Z$, and two angles, must in general be measured to allow of
the determination of $m$ and $n$. The methods of calculation are not altogether simple. The following equations are from Naumann.
(a) Given $X$ and $Y$.
$n$ is found from $\frac{n+1}{n-1}=\frac{\cos \frac{1}{2} X}{\cos \frac{1}{2} Y} ;$ further, $\sin \frac{1}{2} Z=\frac{2 n}{n+1} \cos \frac{1}{2} X$ also,

$$
\cos \xi^{\prime}=\frac{\tan \frac{1}{2} Z}{n \sqrt{3}}, \text { and } \cot \xi^{\prime} \sqrt{\overline{3}}=m c .
$$

(b) Given $X$ and $Z$.

$$
\frac{2 n}{n+1}=\frac{\sin \frac{1}{2} Z}{\cos \frac{1}{2} X} ; \cos \xi^{\prime}=\frac{\tan \frac{1}{2} Z}{n \sqrt{3}} ; \cot \xi^{\prime} \sqrt{3}=m c .
$$

(c) Given $Y$ and $Z$.

$$
\frac{2 n}{n-1}=\frac{\sin \frac{1}{2} Z}{\cos \frac{1}{2} Y} ; \quad \cos \xi^{\prime}=\frac{\tan \frac{1}{2} Z}{n \sqrt{3}}, \text { and } \cot \xi^{\prime} \sqrt{3}=m c .
$$

If $m$, that is the inscribed rhombohedron, is known, one measurement will give the value of $n . \quad Z^{\prime}=$ basal edge of the inscribed rhombohedron (care must be taken to note whether $\phi$ is obtuse or acute).
(d) Given $X$. $\quad \sin \phi=2 \cos \frac{1}{2} X \cos \frac{1}{2} Z^{\prime}$ 。

$$
\tan \left(\phi-\frac{1}{2} Z^{\prime}\right) \cot \frac{1}{2} Z^{\prime}=n .
$$

(e) Given $\dot{Y} . \quad \sin \phi=2 \cos \frac{1}{2} Y \cos \frac{1}{2} Z^{\prime}$ 。

$$
\tan \left(\phi+\frac{1}{2} Z^{\prime}\right) \cot \frac{1}{2} Z^{\prime}=n .
$$

$(f)$ Given $Z . \quad \tan \frac{1}{2} Z, \cot \frac{1}{2} Z^{\prime}=n$.
If $n$ is known. From $X$, we have $\sin \frac{1}{2} Z=\frac{2 n}{n+1} \cos \frac{1}{2} X$; then, as under (a). From $Y, \sin \frac{1}{2} Z=\frac{2 n}{n-1} \cos \frac{1}{2} Y$, and then as above. From $Z$, $\cos \xi^{\prime}$ is obtained as under (a), and then $m c$.

## IV. Orthoriombic System.

Of the three rectangular axes in the Orthorhombic system, one is always taken equal to unity, in this work the shortest (ä). This leaves two unknown quantities to be determined for each specics, namely, the lengths
of the axes $\dot{c}$ and $\bar{b}$, expressed in terms of the unit axis $\breve{a}$, and for this end two independent measurements are required. The simpler cases are aonsidered here.

## Calculation of the Lengths of the Axes.

Let $a=$ the inclination of the edge $Z$ to the axis $\check{a}$ (f.253).
$\beta=$ the inclination of the edge $X$ to the axis $\ddot{\alpha}$.
$\gamma=$ the inclination of the edge $Y$ to the axis $\bar{b}$.
From the plane triangle formed by each edge and the axes adjacent (f. 253,254 ) the following relations are deduced, when $\breve{a}=1$ :
(1) Given $a$ and $\beta$,
$\tan \beta=\dot{c}$ and $\tan a=\bar{b}$.
(2) Given $a$ and $\gamma$, $\tan a=\bar{b}$, and $\bar{b} \tan \gamma=\bar{c}$.
(3) Given $\beta$ and $\gamma$,


The angles $a, \beta, \gamma$ are often giver direct by measurement; for, obviously (f. 254, 255),
$a=$ the semi-prismatic angle $I \wedge I$ (over $i-\bar{i}$ ).
$\beta=$ the semi-basal angle of $1-\bar{\imath} \wedge 1-\bar{i}$.
$\gamma=$ the semi-basal angle of $1-\varkappa \wedge 1-\varkappa$.
Also $I \wedge i-\bar{\imath}=a+90^{\circ} ; 1-\bar{\imath} \wedge i \bar{\imath}=\beta+90^{\circ} ; 1 \bar{\imath} \wedge O=180^{\circ}-\beta$, etc.
From the octahedron (f. 253), the angles $a, \beta, \gamma$ are calculated immediately by the following formulas, and from them the length of the axes as above.
(a) Given $X$ and $Z$ (spherical triangle I, f. 253),

$$
\cos a=\frac{\cos \frac{1}{2} X}{\sin \frac{1}{2} Z} ; \cos \beta=\frac{\cos \frac{1}{2} Z}{\sin \frac{1}{2} X}
$$

(b) Given $Y$ and $Z$ (spherical triangle II, f. 253),

$$
\sin a=\frac{\cos \frac{1}{2} Y}{\sin \frac{1}{2} Z} ; \cos \gamma=\frac{\cos \frac{1}{2} Z}{\sin \frac{1}{2} Y} .
$$

(c) Given $X$ and $Y$ (spherical triangle III, f. 253),

$$
\sin \beta=\frac{\cos \frac{1}{2} Y}{\sin \frac{1}{8} X} ; \sin \gamma=\frac{\cos \frac{1}{2} X}{\sin \frac{1}{2} Y}
$$

If any one of the angles $a, \beta$, or $\gamma$ is given, as from the measurement of a prism or dome, and also any one of the angles of the octahedral edges $X$, $Y$, or $Z$, a second of the former angles may be calculated, and from the two the axes are obtained as before. The formulas, derived from the same spherical triangles, are as follows :
(1) Given $X$ and $a$, $X$ and $\beta$, $X$ and $\gamma$,
(2) Given $Y$ and $a$, $Y$ and $\beta$, $Y$ and $\gamma$,
(3) Given $Z$ and $a$, $Z$ and $\beta$, $Z$ and $\gamma$,

$$
\begin{aligned}
& \sin \beta=\cot \frac{1}{2} X \tan a . \\
& \tan a=\tan \frac{1}{2} X \sin \beta . \\
& \cos \beta=\cot \frac{2}{2} X \cot \gamma . \\
& \sin \gamma=\cot \frac{1}{2} Y \cot a . \\
& \cos \gamma=\cot \frac{1}{2} Y \cot \beta . \\
& \cot a=\tan \frac{1}{2} Y \sin \gamma . \\
& \tan \gamma=\tan \frac{1}{2} Z \cos a . \\
& \cos a=\cot \frac{1}{2} Z \tan \gamma . \\
& \sin a=\cot \frac{1}{2} Z \tan \beta .
\end{aligned}
$$

## Calculation of the values of $m$ and $n$.

The above formulas cover all the ordinary cases, the only change that is required in them is to write for $c, b, a$, in equations (1), (2), (3), above, $c^{\prime}, b^{\prime}, a^{\prime}$, the lengths of the axes for the given form, noting that $c^{\prime}=m c$, and so on.

1. Prisms, $i \cdot \bar{n}$ or $i-{ }^{2}$. As remarked, the semi-prismatic angle (over $i-\overline{-}$ ) is the angle $a$ (f. 254), and $\tan a=n b$. If the calculated value of $n$ is greater than unity, the form is written $\infty c: n b: a(i-\bar{n})$; if less than unity, the form is written oo $c: b: n a(i-n), b$ being the unit axis. Thus $i-\frac{T}{2}$ $\left(\infty c: \frac{1}{2} b: a\right)$ becomes $b-2(\infty \circ: b: 2 a)$.
2. Domes, $m-\bar{\imath}$ and $m$ - $\imath .--N o$ further explanation is needed (f. 255); here $\tan \beta=m c$, or $l \tan \gamma=m c$.
3. Octahedrons, m-Here the angle $a$ is always known (it being the same as for the unitoctahedron where $\tan a=\bar{b}$ ), and hence a single measured angle, $X, Y$, for $Z$ will give the values of either $\beta$ or $\gamma$ for the given form, and $\tan \beta=m c, b \tan \gamma=m c$.
4. Forms $m-\check{h}$ or $m-\check{n}$. - The measurement of the angles $X, Y, Z$ will give the values of $a, \beta$, and $\gamma$ belonging to the given form, and $\tan \beta=m c$, $\tan a=n b$, etc.

Here, as in the prisms, if $n$ is less than unity, when the axis $a$ is the unit, the symbol is transposed, and the axis $\bar{b}$ made the unit, thus $2 c: \frac{1}{2} b: a\left(2-\frac{T}{2}\right)$ becomes $4 c: b: 2 a\left(4-\frac{2}{2}\right)$.

If the angle between the form $m-\bar{n}$ (or $m-r_{n}$ ) and either of the pinacoide can be measured, the method of calculation is essentially the same (Compare f. 248); for
$m-n \wedge O$ (base) $=$ supplement of the angle $\frac{1}{2} Z ;$
$m-n \wedge i-\bar{i}$ (macropinacoid) $=$ supplement of the angle $\frac{1}{2} Y$; and
$m-n \wedge i-i$ (brachypinacoid) $=$ supplement of the angle $\frac{1}{2} X$.

The method of calculation of planes in a rectangular zone by means of the tangents of their supplement basal angles finds a wide application in this system. It applies not only to the main zones $O$ to $i-\bar{i}$ (macrodomes),
$O$ to $i-\imath$ (brachydomes), $i-i$ to $i-\check{\imath}$ (vertical prisms), and $I$ to $O$ (unit octahe drons), but also to any zone of octahedrons $m-\bar{n}$ (or $m-\bar{n}$ ) between $O$ and $i \bar{n}$ (or $i-n$ ), and any transverse zone from $i-\bar{i}$ to $m-\bar{\imath}$, and $i-\bar{\imath}$ to $m-\bar{i}$.

## V. Monoclinic System.



In the Monoclinic system the number of unknown quantities is three, viz., the lengths of the axes $\dot{c}$ and $b$, expressed in terms of the unit clinodiagonal axis $\dot{a}$, and the oblique angle $\beta$ (also called $C$ ), between the basal and vertical diametral sections, that is, between the axes $\dot{c}$ and $\grave{a}$. Three independent measurements are needed to determine these crystallographic elements.

The angle $\beta$ is obtuse in the upper front quadrants, and acute in the lower front quadrants; the planes in the first mentioned quadrants are distinguished from those be. low by the minus sign. The unit octahedron is made up of two hemi-octahedrons ( -1 and +1 ), as shown in f. 256.

Calculation of the Lengths of the Ares, and the Angles of obliquity.
Represent (see f. 256) the inclination of the

> Edge $\underset{X^{\prime}}{X}$ on the axis $\dot{c}$ by $\mu, \quad X$ on $\grave{a}$ by $\nu . \quad Y$ on $\dot{c}$ by $\rho$. $X^{\prime}$ " " $\dot{c}$ " $\mu^{\prime}$. $X^{\prime}$ on $a$ by $\nu^{\prime}$. $Z$ on $a ̀$ by $\sigma$.

For the relation of the axes in terms of these angles we have:
(1) In the oblique-angled plane triangle, in the clinodiagonal section

$$
a: c=\sin \mu: \sin \nu, \text { or, } c=\frac{\sin \nu}{\sin \mu} \text { when } a=1 .
$$

$$
\begin{array}{ll}
\tan \mu=\frac{a \sin \beta}{c-a \cos \beta^{.}} & \tan \mu^{\prime}=\frac{a \sin \beta}{c+a \cos \beta} \\
\tan \nu=\frac{c \sin \beta}{a-c \cos \beta^{.}} & \tan \nu^{\prime}=\frac{c \sin \beta}{a+c \cos \beta} \\
\tan \beta=\frac{2 \sin \mu \sin \mu^{\prime}}{\sin \left(\mu-\mu^{\prime}\right)^{\circ}} & \tan \beta=\frac{2 \sin \nu \sin \nu^{\prime}}{\sin \left(\nu-\nu^{\prime}\right)} .
\end{array}
$$

Further,

$$
\mu+\nu+\beta=180^{\circ}
$$

$$
\mu^{\prime}+\nu^{\prime}=\beta .
$$

(2) In the right-angled triangle of the orthodiagonal section, $b \cot \rho=\alpha$
(3) In the basal section, $\grave{a} \tan \sigma=b$.

The above formulas serve to determine the lengths of the axes and the angle of obliquity, or, if these are known, to determine the values if $m$ and $n$ by substituting $m c$ for $c$, etc.

The angles $\mu, \nu, \rho, \sigma$, etc., must, in general, be determined by calculation from measured angles.

Let the inclination of a plane in the positive quadrant on the clinodiagonal section be denoted by $X$; that on the orthodiagonal section by $Y$; that on the basal section by $Z$. Let also the corresponding inclinations of a plane in the negative quadrants be indicated by $X^{\prime}, Y^{\prime}, Z^{\prime}$, respectively (see f. 20̆6).
It is to be noted, when the pinacoids are present, that

$$
\begin{aligned}
& +1 \wedge O=180^{\circ}-Z ; \quad \begin{array}{l}
1 \wedge i-\bar{i}=180^{\circ}-Y ; \quad+1 \wedge i-i
\end{array}=180^{\circ}-X \\
& -1 \wedge O=180^{\circ}-Z^{\prime} ;-1 \wedge i-\bar{i}=180^{\circ}-Y^{\prime} ; \quad-1 \wedge i-\grave{i}=180^{\circ}-X^{\prime}
\end{aligned}
$$

The same is true for the corresponding angles of the general form $\pm m$-n, or $m-\grave{n}$.
Also, when $\pm 1$ (f. 256) alone are present (or $m-n$ ) note that

$$
+1 \wedge+1=2 X ;-1 \wedge-\underset{(\text { basal })=}{1=2 X^{\prime}} ;+Z^{\prime} \wedge-1 \text { (orthodiag.) }=Y+Y^{\prime} ;
$$

Any three of these angles will serve to give for the unit form ( $\pm 1$ ) the length and obliquity of the axes, or, when these are known, two of these angles are sufficient to deduce the values of $m$ and $n$ for any unknown form.

In the first case, as one of the three measured angles must be either $Y+Y^{\prime}$ or $Z+Z^{\prime}$, the formulas given above do not immediately apply.
For example, if $X, X^{\prime}$ and $Y+Y$ are given. Placing a spherical triangle, $a b c$, in $f .256$, with its vertices on the edges $X, X$, and $Y$, in this the three angles will equal $X, X$ and $Y+Y^{\prime}$ respectively; here the side, $a c$, opposite the angle $\left(Y+Y^{\prime}\right)$ is calculated, which gives the value of $\mu+\mu^{\prime}$, also the side, $b c$, opposite $X^{\prime}$; then, again, in the right-angled spherical triangle, where $b c$ and $X$ are known, $\mu$ is obtained, thus $\mu^{\prime}$ is known and also $\beta$. The lengths of the axes follow from the formulas given above.

The following are some of the cases which may occur:
(a) Given $O$, and $i-i . \quad O \wedge i-i($ front $)=180^{\circ}-\beta$, behind $=\beta$.
(b) Given $O,-1-i$, and $+1-i$. $O \wedge-1-i=180^{\circ}-\nu^{\prime} ; O \wedge+1-i=180^{\circ}$ $-\nu$. By the formula given above, $\tan \beta=\frac{2 \sin \nu \sin \nu^{\prime}}{\sin \left(\nu-\nu^{\prime}\right)}$, also, $\mu=180^{\circ}$. $-(\beta+\nu)$. Thus $\beta, \mu$, and $\nu$ are known, and from thein the relation of the axes $\dot{a}$ and $\dot{c}$ is deduced.
(c) Given $i-i,-1-i$ and $+1-i$. $i-i \wedge-1-i=180^{\circ}-\mu^{\prime}, i-i \wedge+1-i=180^{\circ}$
$-\mu$. As before, $\tan \beta=\frac{2 \sin \mu \sin \mu^{\prime}}{\sin \left(\mu-\mu^{\prime}\right)}$, and $\nu=180^{\circ}-(\beta+\mu)$.
(d) Given the prism $I$ and $O$ (f.257). In the spherical triangle $A B C$, $C=90^{\circ}$ (inclination of base on cli_iodiagonal section), $B=O \wedge I, A=$ $\frac{1}{8}(I \wedge I)$. Hence, the sides $C A$ and $C B$ are calculated; $C A=\beta$ (or, as
 in this case, $180^{\circ}-\beta$ ) ; $C B=\sigma$, which gives the ratio of the lateral axes, $a$ and $b$.
(e) Given $i-i, 1-i$ and $O . \quad O \wedge i-i$ (behind) $=\beta$, and $\sin \beta \tan \left[(0 \wedge 1-i)-90^{\circ}\right]=\tan \rho$.
$(f)$ Given +1 and -1 , form as in f. 256. The angles between the planes +1 and -1 and the diametral sections are indicated by the letters $X, Y$, etc., as before explained (p. 77). The relations between these angles and the angles $\mu, \nu, \rho$, etc., are given in the following formulas, deduced by means of spherical triangles:

$$
\begin{aligned}
& \cos \mu=\frac{\cos Y}{\sin X}, \quad \cos \mu^{\prime}=\frac{\cos Y^{\prime}}{\sin X^{\prime}}, \quad \cos \cdot \rho=\frac{\cos X}{\sin Y}=\frac{\cos X^{\prime}}{\sin Y^{\prime}} \\
& \cos \nu=\frac{\cos Z}{\sin X}, \quad \cos \nu^{\prime}=\frac{\cos Z^{\prime}}{\sin X^{\prime}}, \quad \cos \sigma=\frac{\cos X}{\sin Z}=\frac{\cos X^{\prime}}{\sin Z^{\prime}}
\end{aligned}
$$

alsc,

$$
\tan X=\frac{\tan \sigma}{\sin \nu}=\frac{\tan \rho}{\sin \mu}, \quad \tan X^{\prime}=\frac{\tan \sigma}{\sin \nu^{\prime}} \quad \frac{\tan \rho}{\sin \mu^{\prime}} .
$$

$\tan Y=\frac{\tan \mu}{\sin \rho}, \quad \tan Y^{\prime}=\frac{\tan \mu^{\prime}}{\sin \rho}, \quad \tan Z=\frac{\tan \nu}{\sin \sigma}, \quad \tan Z^{\prime}=\frac{\tan \nu^{\prime}}{\sin \sigma}$.

(g) Given the prism $I$ and -1 (or +1 ). The angles $I \wedge I,-1 \wedge I,-1 \wedge-1$ are measured. In the spherical triangle $A B D$ (f. 258), the angle $A=\frac{1}{2}(I \wedge I), B=-$ $1 \wedge I, D=\frac{1}{2}(-1 \wedge-1)=X^{\prime}$, from which the sides $A D$ $=\nu^{\prime}+\left(180^{\circ}-\beta\right)$ and $A B$ are calculated. Then in the second triangle, $A B C, C=90^{\circ}, A B$ is known, also $A$; ence, $C B=\sigma$ and $C A=180^{\circ}-\beta$ are calculated. Thus $r^{\prime}$ and $\mu^{\prime}$ and $\beta$ become known, and the relation of $a$ to $d$; also from $\sigma$ follows the ratio of $a$ to $b$.

## Calculation of the values of $m$ and $n$.

In general, it may be said that the methods of calcnlation are the same ds those already given. In each case the values of $\mu, \nu, \rho, \sigma$ are to be obtained, and those introduced into the axial equations ( $1,2,3$ ) given above give the values of $m c, n b$, etc., from which $m$ and $n$ are derived. When in the general form $m-n(m c: n b: a) n$ is found to be less than unity, then $b$ is made the unit axis and the form is written $m-\grave{n}$ ( $m c$ : $b: n a$ ), thus $2 c: \frac{1}{2} b: a$ becomes $4 c: b: 2 a(4-2)$, the same is true for $i-n$ and $i-n$.

1. Hemi-octahedrons, $\pm m-n$. .Two measurements are needed, giving
two of the angles $X, Y, Z$, etc., from which are derived $\mu$ (or $\nu$ ), $\rho$ (or $\sigma$ ), and from the proper formulas $m$ and $n$.

The following hemi-octahedrons require one measurement only: $\pm m$, $\pm m-m, \pm m-\bar{m}, \pm 1-n, \pm 1-\grave{n}$. Further, it is to be noted in regard to them that the forms $\pm m$ have the same ratio of the lateral axes as $\pm 1$, that is, the same value of $\sigma$.

Forms $\pm 1-n$, and $\pm m-m$, have the same ratio of the axes $\dot{c}$ and $\dot{a}$ as the unit form $\pm 1$, that is, the same values of $\mu, \nu\left(\mu^{\prime}, \nu^{\prime}\right)$.

Forms $\pm m-m, \pm 1-\grave{n}$, have the same ratio of the axes $c$ and $b$ with $\pm 1$, that is, the same value of $\rho$.
2. Form $i-n$ (or $i-n$ ).-If, as before, $X, Y$ represent the inclinations of the given prism on the clinodiagonal and orthodiagonal sections respectively, it is to be noted that:

$$
X+Y=90^{\circ}
$$

Similarly to f. 257, we obtain, in general, for any form, $i-n$,

$$
n=\frac{\sin \beta \tan X}{b} ; \text { and for } i-\grave{n}, n=\frac{b \cot X}{\sin \beta}
$$

Since $i-i \wedge i-\grave{\imath}=90^{\circ}$, the tangent law can be applied in this zone advan tageously. If $X^{1}, Y^{1}$ are the corresponding angles for the unit prism $I$, then for $i-n$,

$$
n=\frac{\tan X}{\tan X^{1}}=\frac{\tan Y^{1}}{\tan Y^{1}}, \quad \text { and for } i-\grave{n}, n=\frac{\tan X^{1}}{\tan X^{1}}=\frac{\tan Y}{\tan Y^{1}}
$$

3. Forms $\pm m$ - $i$, hemi-orthodomes.-For each form the corresponding values of $\mu, \nu\left(\mu^{\prime}, \nu^{\prime}\right)$ are to be obtained by measurement or else calculated, and from them the value of $m c$ obtained from the formulas (1), $m c=$ $\frac{\sin \nu}{\sin \mu}$, etc.
4. Forms $m$ - $̀$, clinodomes.-Similarly as with the prisms, when $X$ and $Z$ denote the angles with the clinodiagonal and basal sections,

For any form $m-i$,

$$
\begin{gathered}
X+Z=90^{\circ} \\
m=\frac{b \cot X}{c \sin \beta}
\end{gathered}
$$

Or by the tangent law, $X^{1}$ being the corresponding angle for $1-\hat{\ell}$,

$$
m=\frac{\tan X^{1}}{\tan \bar{X}}
$$

## Triclinto System.

The triclinic system is characterized by its entire want of symmetry The inclisations of all the diametral planes, and hence, the inclination of the axes, are oblique to one another. There are, then, five unknown quantities to be determined in each case, viz., the three angles of obliquity of the axes, and the lengths of the axes $\bar{b}$ and $\dot{c}, \breve{a}$ being made $=1$.

The axes are lettered as in the orthorhombic system: $\dot{c}=$ the vertical axis, $\bar{b}=$ the macrodiagonal axis, and $\check{a}=$ the brachydiagonal axis.

Let (f. 259) $a=$ angle between the axes $\dot{c}$ and $\bar{b}$;
 $\beta=$ angle between the axes $\dot{c}$ and $\check{a}$; $\gamma=$ angle between the axes $\bar{b}$ and $\check{u}$. Also, let $A=$ angle of inclination of the diametral planes meeting in the axis $\breve{a} ; B=$ angle of inclination for those intersecting in the axis $\bar{b}$, and $C=$ the angle of those meeting in $\dot{c}$.

The macrodiagonal ( $m-\bar{n}$ ) and brachydiagonal ( $m-h_{n}$ ) planes are indicated as in the orthorhombic system, also the planes opposite the acute angle $(\beta)$ are called + , and those opposite the corresponding obtuse angle - ; furthermore, the planes in front, to the right (and behind, to the left) are distinguished by an accent, as $m-n^{\prime}$.

In the fundamental octahedron formed by four sets of planes, these are, taken in the usual order ( $f .227$ ) , $-1^{\prime},-1,+1^{\prime},+1$, and below, $+1^{\prime}$, $+1,-1^{\prime},-1$.

In the determination of any individual crystal belonging to this system, the axial directions as well as unit values have to be assumed arbitrarily; in many cases (e.g., axinite) the custom of different authors has varied much. Two points are to be considered in making the choice: 1 , the correspondence in form with related species, even if these be not triclinic, as, for example, in the feldspar family; and 2 , the ease of calculation, which is much facilitated if, of the planes chosen as fundamental, the pinacoids are all, or at least in part, present.

In general, the methods of calculation are not simple. Some of the most important relations are given here (from Naumann). In actual practice, problems which arise may be solved by some of the following formulas, or by means of a series of appropriate spherical triangles, used as in the preceding pages, and by which, from the measured angles, the required elements of the forms may be obtained.

In addition to the angles already defined, let, as follows.(f. 259),
$\underset{\nabla}{X}=$ inclination of a plane on the brachydiagonal section;
$Y=\quad$ " $\quad$ " $\quad$ " $\quad$ " $\quad$ macrodiagonal $\quad$ "

Let the inclination of the edge,

$$
\begin{array}{lll}
X \text { on } \dot{c}=\mu, & Y \text { on } \dot{c}=\rho, & Z \text { on } \breve{a}==\sigma, \\
X \text { on } \check{a}=\nu, & Z \text { on } \bar{b}=\pi, & Z \text { on } \bar{b}=\tau,
\end{array}
$$

When the three pinacoids are present, the angles $A, B, C$ are given by measurement. These angles are connected with the axial angles by the following equations:

$$
\begin{gathered}
\cos a=\frac{\cos A+\cos B \cos C}{\sin B \sin C} ; \quad \cos \beta=\frac{\cos B+\cos C \cos A}{\sin C^{\gamma} \sin A} ; \\
\cos \gamma=\frac{\cos C+\cos A \cos B}{\sin A \sin B} ;
\end{gathered}
$$

also,

$$
\sin a: \sin \beta: \sin \gamma=\sin A: \sin B: \sin C .
$$

The relations between the angles $a, \beta, \gamma$, and the angles $\mu, \nu$, etc., are as foliows:

$$
\begin{aligned}
& \tan a=\frac{2 \sin \rho \sin \rho^{\prime}}{\sin \left(\rho-\rho^{\prime}\right)}=\frac{2 \sin \pi \sin \pi^{\prime}}{\sin \left(\pi-\pi^{\prime}\right)} \\
& \tan \beta=\frac{2 \sin \mu \sin \mu^{\prime}}{\sin \left(\mu-\mu^{\prime}\right)}=\frac{2 \sin \nu \sin \nu^{\prime}}{\sin \left(\nu-\nu^{\prime}\right)} \\
& \tan \gamma=\frac{2 \sin \tau \sin \tau^{\prime}}{\sin \left(\tau-\tau^{\prime}\right)}=\frac{2 \sin \sigma \sin \sigma^{\prime}}{\sin \left(\sigma-\sigma^{\prime}\right)} .
\end{aligned}
$$

Also,

$$
a+\pi+\rho=\beta+\mu+\nu=\gamma+\sigma+\tau=180^{\circ} .
$$

The relations between $X, Y, Z$, and $A, B, C$, and $\mu, \nu$, etc., are given by the following formulas, in which the sum and difference of $X$ and $Y$, etc., are calculated, and from them the angles $X, Y$, etc., themselves are obtained :

$$
\begin{aligned}
& \tan \frac{1}{2}(X+Y)=\cot \frac{1}{2} C \cdot \frac{\cos \frac{1}{2}(\rho-\mu)}{\cos \frac{1}{2}(\rho+\mu)^{\circ}} \\
& \tan \frac{1}{2}(X-Y)=\cot \frac{1}{2} C \cdot \frac{\sin \frac{1}{2}(\rho-\mu)}{\sin \frac{1}{2}(\rho+\mu)^{\circ}} \\
& \tan \frac{1}{2}(X+Z)=\cot \frac{1}{2} A \cdot \frac{\cos \frac{1}{2}(\sigma-\nu)}{\cos \frac{1}{2}(\sigma+\nu)^{\circ}} \\
& \tan \frac{1}{2}(X-Z)=\cot \frac{1}{2} A \cdot \frac{\sin \frac{1}{2}(\sigma-\nu)}{\sin \frac{1}{2}(\sigma+\nu)^{\circ}} \\
& \tan \frac{1}{2}(Y+Z)=\cot \frac{1}{2} B \cdot \frac{\cos \frac{1}{2}(\tau-\pi)}{\cos \frac{1}{2}(\tau+\pi)^{\circ}} \\
& \tan \frac{1}{2}(Y-Z)=\cot \frac{1}{2} B \cdot \frac{\sin \frac{1}{2}(\tau-\pi)}{\sin \frac{1}{2}(\tau+\pi)^{\circ}} .
\end{aligned}
$$

$$
\begin{aligned}
& \cos \mu=\frac{\cos Y+\cos X \cos C}{\sin X \sin C}, \quad \cos \nu=\frac{\cos Z+\cos X \cos A}{\sin X \sin A} . \\
& \cos \rho=\frac{\cos X+\cos Y \cos C}{\sin Y \sin C}, \quad \cos \pi=\frac{\cos Z+\cos Y \cos B}{\sin Y \sin B} . \\
& \cos \sigma=\frac{\cos X+\cos Z \cos A}{\sin Z \sin A}, \quad \cos \tau=\frac{\cos Y+\cos Z \cos B}{\sin Z \sin B} .
\end{aligned}
$$

Further,

$$
\begin{aligned}
& \sin X: \sin Y=\sin \rho: \sin \mu . \\
& \sin Y: \sin Z=\sin \tau: \sin \pi \\
& \sin Z: \sin X=\sin \nu: \sin \sigma .
\end{aligned}
$$

The following equations give the relations of the angles $\mu, \nu, \rho$, etc to the axes and axial angles:

$$
\begin{array}{ll}
\tan \mu=\frac{a \sin \beta}{c-a \cos \beta} ; \quad \tan \nu=\frac{c \sin \beta}{a-c \cos \beta} . \\
\tan \rho=\frac{b \sin a}{c-b \cos a} ; \quad \tan \pi=\frac{c \sin a}{b-c \cos a} . \\
\tan \tau=\frac{a \sin \gamma}{b-a \cos \gamma} ; \quad \tan \sigma=\frac{b \sin \gamma}{a-b \cos \gamma} .
\end{array}
$$

Also,

For any form $m-n$,

$$
m-n \wedge i-\bar{i}=180^{\circ}-Y ; m-n \wedge i-\imath=180^{\circ}-X ; m-n \wedge O=180^{\circ}-Z
$$

For a vertical hemiprism, $X+Y+C=180^{\circ}$,

$$
\check{a}: \bar{b}=\sin Y . \sin a: \sin X: \sin \beta .
$$

For a macrodiagonal hemidome, $Y+Z+B=180^{\circ}$,

$$
\check{a}: \dot{c}=\sin Y \cdot \sin a: \sin Z \cdot \sin \gamma .
$$

For a brachydiagonal hemidome, $X+Z+A=180^{\circ}$,

$$
\bar{b}: \dot{c}=\sin X \sin \beta: \sin Z \sin \gamma
$$

By writing $m c$ for $c, n b$ for $b$, etc., these formulas will answer also for the determination of $m$ and $n$. It is supposed in the above that the measured edge is parallel to the axis of the given hemiprism, etc.; when this is not the case the relations are a little less simple.

## Measurement of the Angles of Crystals.*

The angles of crystals are measured by means of instruments which are called goniometers.

The simplest form of these instruments is the hand-goniometer, represented in f. 260. It consists of an arc, graduated to half degrees, or finer,

and two movable arms. In the instrument figured, one of the arms, $a v$, has the motion forward and backward by means of slits $g h, i k$; the other arm, $c d$, has also a similar slit, and in addition it turns around the centre of the arc as an axis. The planes whose inclination is to 'be measured are applied between the arms $a, c o$, and the latter adjusted so that they and the surfaces of the planes are in close contact. This adjustment must be made with care, and when the instrument is held up to the light none must pass through between the arm and the plane. The nnmber of degrees read off on the are between $k$ and the left edge of $d$ (this edge being in the line of the centre, $o$, of the arc) is the angle required. The motion to and fro by means of the slits is for the sake of convenience in measuring small or imbedded crystals. In a much better form of the instrument the arms are wholly separated from the arc; and the are is a delicately graduated circle to which the arms are adjusted after the measurement.

The hand-goniometer is useful in the case of large crystals, and those whose faces are not well polished ; the measurements with it, however, are seldom within a quarter of a degree of accuracy. In the finest specimens of crystals, where the planes are smooth and lustrous, results far more accurate may be obtained by means of a different instrument, called the reflecting goniometer.

Reflecting Goniometer.-This instrument was devised by Wollaston, in 1809, but it has been much improved in its various parts since his time, especially by Mitscherlich. The principle on which it is constructed may be understood by reference to the following figure (f.261), which represents a crystal, whose angle, $a b c$, is required.

The eye at $P$, looking at the face of the crystal, $3 c$, observes a reflected

[^7]image of $m$, in the direction of $P_{n}$. The crystal may now be so changed in its position, that the same image is seen reflected by
 the next face and in the same direction, Pn. 'To effect this, the crystal must be turned around, until $a b d$ has the present direction of $b c$. The angle $d b c$, measures, therefore, the number of degrees through which the crystal must be turned. But $d b c$, subtracted from $180^{\circ}$, equals the required angle of the crystal, $a b c$. The crystal is, therefore, passed in its revolution through an angle which is the supplement of the required angle. This

angle evidently may be measured by attaching the crystal to a graduated circle, which should turn with the crystal.

The accompanying cut (f. 262) represents a reflecting goniometer made
by Oertling, in Berlin. It will suffice to make clear the general character of the instrument, as well as to exhibit some of the refinements added for the sake of greater exactness.

The circle, $C$, is graduated, in this case, to twenty minutes, and by means of the vernier at $v$ the readings may be made to minutes and half minutes. The crystal is attached by means of wax to the little plate at $\%$; this may be removed for convenience, but in its final position it is, as here, at the extremity of the axis of the instrument. This axis is moved by means of the wheel, $n$; the graduated circle is moved by the wheel, $m$. These motions are so arranged that the motion of $n$ is independent, its axis being within the other, while on the other hand the revolution of $m$ moves both the circle and the axis to which the crystal is attached. This arrangement is essential for convenience in the use of the instrument, as will be seen in the conrse of the following explanation.

The screws, $c, d$, are for the adjustment of the crystal, and the slides, $a, b$, serve to centre it.

The method of procedure is briefly as follows: The crystal is attached by means of suitable wax at $k$, and adjusted so that the direction of the combination-edge of the two planes to be measured coincides with the axis of the instrument ; the wheel, $n$, is turned until an object (e.g., a windowbar) reflected in one plane is seen to coincide with another object not reflected (e.g., a chalk line on the floor), the position of the graduated circle is observed, and then both crystal and circle revolved together by means of the wheel, $m$, till the same reflected object now seen in the second plane again coincides with the fixed object (that is, the chalk line); the angle through which the circle has been moved, as read off by means of the vernier, is the supplement angle between the two planes.

In order to secure accuracy, several conditions must be fultilled, of which the following are the most important:

1. The position of the eye of the observer must remain perfectly stationary.
2. The object reflected and that with which it is brought in coincidence, should be at an equal distance from the instrument, and this distance should not be too small.
3. The crystal inust be accurately adjusted; this is so when the line seen reflected in the case of each plane and that seen directly with which it is in coincidence are horizontal and parallel. It can be true only when the intersection edge of the two planes neasured is exactly in the direction of the axis of the instrument, and perpendicular to the plane of the circle.
4. The crystal must be centered as nearly as possible, or, in other words, the same intersection-edge must coincide with a line drawn through the revolving axis. This condition will be seen to be distinct from the preceding, which required only that the two directions should be the same. The error arising when this condition is not satisfied diminishes as the object reflected is removed farther from the instrument, and becomes zero if the object is at an infinite distance.

The first and second conditions are both satisfactorily fulfilled by the use of a telescope, as $t$, f. 262, with slight magnifying power. This is arranged for parallel light, and provided with spider lines in its focus. It admits also of some adjustments, as seen in the figure, but
when nsed it must be directed exactly toward the axis of the gonometer. This telescope has also a little magnifying glass ( $g$, f. 262) attached to it, which allows of the crystal itself being seen when mounted at $k$. This latter is used for the first adjustments of both planes, and then slipped aside, when some distant object which has been selected must be seen in the field of the telescope as reflected, first by the one plane and then by the other as the wheel $n$ is revolved. When the final adjustments have been made so that in each case the object coincides with the centre of the spider-cross of the telescope, and when further the edge to be measure $\bar{i}$ has been centered, the crystal is ready for measurement.

This telescope, obviously, can be used only when the plane is smooth and large enough to give distinct and brilliant reflections. In many cases sufficient accuracy is obtained without it by the use of a window-bar and a white chalk line on the floor below for the two objects ; the instrument in this case is placed at the opposite end of the room, with its axis parallel to the window; the eye is brought very close to the crystal and held motionless during the measurement.

The best instruments are provided with two telescopes. The second stands opposite the telescope, $t$ (see figure), the centres of both telescopes being in the same plane perpendicular to the axis of the instrument. This second telescope has also a hair cross in the focus, and this, when illuminated by a brilliant gas burner (the rest of the instrument being protected from the light by a screen) will be reflected in the successive faces of the crystal. The reflected cross is brought in coincidence with the cross in the first telescope, first for one and then for the other plane. As the lines are delicate, and as exact coincidence can take place only after perfect adjustment, it is evident that a high degree of accuracy is possible.
Still more than before, however, are well-polished crystals required, so that in the majority of cases the use of the ordinary double telescopes is impossible. Very often, however, the second telescope may be advantageously replaced by another having an adjustable slit in its focus, as proposed by Websky, allowing of being made as narrow as is convenient; or, as suggested by Schrauf, the spider-lines of the second telescope may be replaced by a piece of tin-foil, in which two fine cross lines have been cut; these are illuminated by a gas-burner. By these methods the reflected object is a bright line or cross, instead of the dark spider-lines, and it is visible in the first telescope even when the planes are extremely minute, or, on the other hand, somewhat rough and uneren; the image is naturally not perfectly distinct, but sufficiently so to admit of good measurements (e.g., within two or three minutes).

The third and fourth conditions are the most difficult to fulfil absolutely. In the cheaper instruments the contrivance to accomplish the end often consists of a jointed arm so placed as to have two independent motions at right angles to each other. In the best instruments the greatest care and attention is paid to this point, and a great variety of ingenious contrivances have been devised to overcome the various practical difficulties arising.

The cut (f. 262) shows one of these in its simpler form. The crystal is approximately adjusted by the hand, and then the operation completed by means of the screws $c$ and $d$. These give two motions at right angles to
each other, and the arrangement is such that the motions are made on the surface of a spherical segment of which the crystal itself occupies the centre, so that it is not thrown entirely out of the axis of the instrument by the motions of the screws. The adjustment having been accurately made, the edge is centered by means of two sliding carriages, $a, b$, moving at right angles to each other; here they are moved by haud, but in better instruments by tine screws. The edge must be first centered as carefully as practicable, then the complete adjustments made, and finally again centered, as before, to remove the excentricity caused by the movement of the adjustment screws. The successful use of the most elaborate instruments is only to be attained after much patient practice.

Theoretical discussions of the various errors arising in measurements and the weight to be attached to them have been given by Kuppfer (Preisschrift über genane Messung der Winkel an Krystallen, 1825), also by Naumann, Grailich, Schrauf, and others (see literature, p. iv).

It has been stated that when the two planes have been adjusted in the goniometer so that their combination-edge is parallel to the axis of the instrument, the reflections given by them will be parallel. It is evident from this that any other planes on the crystal which are in the same zone with the two mentioned planes will also give, as the circle is revolved, reflections parallel to these. This means gives the test referred to on p. 53, leading on the one hand to the discovery of zones not indicated by parallel intersections, and on the other hand showing, in regard to supposed zones, whether they are so in fact or not.

The degree of accuracy and constancy in the angles of crystals as they are given by natare is an important subject. Crystallography as a science is based upon the assumption that the forms made by nature are perfectly accurate, and whenever exact measurements are possible, supposing the crystals to have been free from disturbing influences, it has been found that this assumption is warranted by the facts; in other words, the more accurate the measurements the moreclosely do the angles obtained agree with those required by theory. An example may illustrate this:-On a crystal of sphalerite (zinc-blende), from the Binnenthal, exact measurements were made by Kokscharow to test the point in question. He found for the angle of the tetrahedron $70^{\circ} 31^{\prime} 48^{\prime \prime}$, required $70^{\circ} 31^{\prime} 44^{\prime \prime}$; for the octahedral angle $109^{\circ} 27^{\prime} 42^{\prime \prime}$, required $109^{\circ} 28^{\prime} 16^{\prime \prime}$; and for the angle between the tetrahedron and cabe $125^{\circ} 15^{\prime} 52^{\prime \prime}$, required $125^{\circ} 15^{\prime} 52^{\prime \prime}$. The crystallographic works of the same author, as well as those of many other workers in the same field, contain many illustrations on the same subject. At the same time variations in angle do occasionally occur, from a change in chenaical composition, and from various disturbing causes, such as heat and pressure (see further, p. 107). Further than this, it is universally true that exact measurements are in comparatively few cases possible. Many crystals are large and rough, and admit of only approximate results with the hand goniometer; others have faces which are more or less polished, but which give uncertain reflections. This is due in some cases to striations, in others to the fact that the surfaces are curved or more or less covered with markings or etchings, like those common on the pyramidal planes of quartz. In all such cases there is a greater or less discrepancy between the measured and calculated angles.

The important point to be noted always is the degree of accuracy attainable, or, in other words, the probable error. The true result to be accepted is always to be obtained by the discussion of all the measurements in accordance with the methods of least squares. This method involves considerable labor, and in most cases it is sufficient to take the arithmetical mean, noting what degree of weight is to be attached to each measurement. It is to be noted that where measurements vary largely the probable error in the mean accepted will be considerable; moreover in approximate measurement may not be the more accurate because it happens to agree closely with the theoretical angle.

For the determination of the symbols of planes, measurement accurate within 30', or even $1^{\circ}$, are generally sufficient.
When planes are rough and destitute of lustre the angles can best be obtained with the
reflecting goniometer, the reflections of the light from an object like a candle flame, being taken in place of more distinct images.
For imbedded crystals, and often in other cases, measurements may be very advantago ously made from impressions in some material, like sealing-wax. Angles thus obtained ought to be accurate within one degree, and suffice for many purposes. It is sometimes of advantage to attach to the planes to be measured, when quite rough, fragments of thin glass, from which reflentions can be obtained; this must, however, be done with care, to avoid considerable error.

## COMPOUND, OR TWIN CRYSTALS.

Twin orystals are those in which one or more parts regularly arrranged are in reverse position with reference to the other part or parts. They often appear externally to consist of two or more crystals symmetrically united, and sometimes have the form of a cross or star. They also exhibit the composition in the reversed arrangement of part of the planes, in the striæ of the surface, and in re-entering angles; in other cases the compound structure is detected only by polarized light. The following figures are examples of the simpler kinds. Fig. 263 is a twinned octahedron with

re-entering angles. Fig. 263a represents the regular octahedron divided into two halves by a plane parallel to an octahedral face; the revolving of the upper half aromed $180^{\circ}$ produces the twinned form. Fig. 264 consists of a square prism, with pyramidal terminations, twinned parallel to a diagonal plane between opposite solid angles, as illustrated in f. 264A, a representation of the simple form. A revolution of one of the two halves of f. $264 \mathrm{~A} 180^{\circ}$ about an axis at right angles to the diagonal plane outlined in the figure, would produce the form in fig. 264.

Crystals which occupy parallel positions with reference to each other, that is, those whose similar axes and planes are parallel, are not properly called twins; the term is applied only where the crystals are united in their reversed position in accordance with some deducible mathematical law. In conceiving of them we imagine first the tivo individuals or portions of the same individual to be in a parallel position, and then a revolution of $180^{\circ}$ to take place about a certain line, as axis, which will bring them into the twinning position.

[^8]In some cases (e.g., hexagonal forms), a revolution of $60^{\circ}$ would produce the twinned form, but in treating of the subject it is better to make the uniform assumption of a revolu tion of $i 8 U^{\circ}$, which will answer in all cases.

It is not to be supposed that twins have actually been formed by such a revolution of the parts of crystals, for the twin is the result of regular molecular growth or enlargement, like that of the simple crystal. This reference to a revolution, and an axis of revolution, is only a convenient means of describing the forms. But while this is true, it is important to observe that the laws deduced to explain the twinning of a crystal have, from a molecular standpoint, a real existence. The measurements of Schrauf on twins of cerussite (Tsch. Min. Mitth., 1873, 209) show the complete correspondence between the actual angles and those required in accordance with the law of twinning.

Twinning axis.-The line or axis about which the revolution of $180^{\circ}$ is supposed to take place is called the twinning-axis (Zwillingsaxe, Germ.), or axis of revolution.

The following law has been deduced in regard to this axis, upon which the theory of the whole subject depends:

The twinning axis is always a possible crystallographic line, usually either an axis or a normal to some possible crystalline plane.

Twinning-plane. -The plane normal to the axis of revolution is called the twinning-plane (Zwillingsfläche, Germ.). The axis and plane of twinning bear the same relation to both individuals in their reversed position; consequently (except in some of hemihedral and triclinic forms) the twinned crystals are symmetrical with reference to the twinning-plane.

Composition-plane.-The plane by which the reversed crystals are united is the composition-plane or -face (Zusammensetzungsfläche, Germ.). This and the twinning-plane very commonly coincide; this is true of the simple examples given above (f. 263,264 ) where the plane about which the revolution is conceived as having taken place (normal to the twinning axis), and the plane by which the semi-individuals are united, are identical. When not coinciding the two planes are generally at right angles to each other, that is, the composition face is parallel to the axis of revolution. Examples of this are given beyond (p.99). Still again, where the crystals are not regularly developed, and where they interpenetrate, and, as it were, exercise a disturbing influence upon each other, the contact surface may be interrupted, or inay be exceedingly irregular. In such cases the axis and plane of twinning have, as always, a detinite position, but the compositionface has lost its significance.

Thus in quartz the interpenetrating parts have often no rectilinear boundary, but mingle in the most irregular manner throughout the mass, and showing this composite irregularity by abrupt variations of the planes at the surface. Fig. 265 exhibits by its shaded part the parts of the plane -1 that appear over the surface of the plane $R$, owing to the interior composition. This internal structure of quartz, found in almost all quartz crystals, even the common kinds, is well brought out by means of polarized light; also, by etching with hydrofluoric acid, the plane -1 and $R$ becoming etched unequally on the same amount of exposure to the acid.

The twinning-plane is, with rare exceptions, a possible occurring plane on the given species, and usnally one of the more
frequent or fundamental planes. The exceptions occur only in the triclinic and monoclinic systems, where the twinning axis is sometimes one of the oblique crystallographic axes, and then the plane of twinning normal to it is obviously not necessarily a crystallographic plane, this is conspicuous in albite. In these cases the composition-face is often of more significance than the twinning-plane, the former being distinct and parallel to the axis, in accordance with the principle stated above.

With reference to the composition-face, the twinning may be described as taking place (1) by a revolution on an axis at right angles to the composition-face, (2) on an axis parallel to it and vertical, (3) by an axis parallel to it and horizontal; whether the revolution takes place with the right or left half of the crystal, the twin is right- or left-handed.

One further principle is of theoretical importance in the mathematical explanation of the forms. The twinning axis may, in many cases, be exchanged for another line at right angles with it, a revolution about which will also satisfy the conditions of producing the required form. An example of this is furnished by f. 318, of orthoclase; the composition-face is parallel to $i-i$, the axis of revolution also parallel to this plane, and (a) norinal to $i-i$, which is then consequently the twinning-plane, though the axis does not coincide with the crystallographic axis, or (b) it may coincide with the vertical axis, and then the twinning-plane normal to it is not a crystallographic plane. In other simpler cases also, the same principle holds good, generally in consequence of the possible mutual interchange of the planes of twinning and composition. In most cases the true twinning-plane is evident, since it is parallel to some plane on the crystal of simple mathematical ratio.

An interesting example of the above principle is furnished by the species staurolite. Fig. 307, p. 98, shows a prismatic twin observed by the author among crystals from Fannin Co., Ga. The measured angle for $i-i \wedge \wedge i-\imath^{\prime}$ was $70^{\circ} 30^{\prime}$; the twinning-axis deduced from this may be the normal to the plane $i \cdot \frac{3}{2}$, which would then be the twinning-plane. Instead of this axis, ite complementary axis at right angles to it may be taken, which will equally well produce the observed form. Now in this species it happens that the planes $i-\frac{5}{3}$ and $i-\frac{3}{2}$ (over $i-\bar{i}$ ) are almost exactly at right angles ( $90^{\circ} 8^{\prime}$ ) with each other, and hence, according to this latter supposition, $i-\frac{3}{3}$ becomes the twinn ng-plane, and the axis of revolution is normal to it. Hence, either $i-\frac{3}{2}$ or $i-\frac{3}{3}$ may be the twinning-plane, either supposition agrees closely with the measured angle, which could not be obtained with great accuracy. The former method of twinning $\left(i-\frac{\overline{3}}{2}\right)$ conforms to the other twins observed on the species, and hence it may be accepted. What is true in this case, however, is not always true, for it will seldom happen that of the two complementary axes each is so nearly normal to a plane of the crystal. In most cases one of the two axes conforms to the law in being a normal to a possible plane, and the other does not, and hence there is no doubt as to which is the true twinning axis.

Contact-twins and Penetration-twins.-In contact-twins, when normally formed, the two halves are simply connate, being united to each other by the composition-face; this is illustrated by f. 263, 264. In actually occurring crystals the two parts are seldom symmetrical, as demanded by theory, but one may preponderate to a greater or less extent over the other; in some cases only a small portion of the second individual in the reversed position may exist. Very great irregularities are observed in nature in this respect. Moreover, the re-entering angles are often obliterated by the abnormal developments of one or other of the parts, and often only an indis-
tinct line on some of the faces marks the division between the twc individuais.

Penetration-twins are those in which two or more complete crystals interpenetrate, as it were crossing through each other. Normally, the crystals have a common centre, which is the centre of the axial system for both; practically, however, as in contact-twins, great irregularities occur.

Examples of these twins are given in the annexed figures, f. 266, of fluorite, and f. 267, of hematite. Other examples occur in the pages following, as, for instance, of the species staurolite, f. 309 to 312 , the crystals of which sometimes occur in nature with almost the perfect symmetry demanded by theory. It is obvious that the distinction between contact and penetration-twins is


Fluorite. not a very important one, and the line cannot always be clearly drawr. between them.

Paragenic and Metagenic twins.-The distinction of paragenic and metagenic twins belongs rather to crystallogeny than crystallography. Yet the forms are often so obviously distinct that a brief notice of the distinction is important.

In ordinary twins, the compound structure had its beginning in a nucleal compound molecule, or was componnd in its very origin; and whatever inequalities in the result, these are only irregnlarities in the development from such a nucleus. But in others, the crystal was at first simple ; and afterwards, through some change in itself or in the condition of the material supplied for its increase, received new layers, or a continuation, in a reversed position. This mode of twinning is metagenic, or a result subsequent to the origin of the crystal; while the ordinary mode is paragenic. One form of it is illustrated in f. 268. The middle portion had attained a length of half an inch or more, and then became geniculated simultaneously at either extremity. These geniculations are often repeated in rutile, and the ends of the crystal are thus bent into one another, and occasionally produce nearly regular prismatic forms.

This metagenic twinning is sometimes presented by the successive layers of deposition in a crystal, as in some quartz crystals, especially amethyst, the inseparable layers, exceedingly thin, being of opposite kinds. So calcite crystals are sometimes made up of twinned layers, which are due to an oscillatory


Ratile. process of twinning attending the progress of the crystal In a similar manner, crystals of the triclinic feldspars, albite, etc., are often made up of thin plates parallel to $i-\check{\iota}$, by oscillatory composition, and the face $O$, accordingly, is finely striated parallel to the edge $0 \wedge i-\ell$.

Repeated twinning.-In the preceding paragraph one case of repeated twinning has been mentioned, that of the feldspars; it is a case of parallel repetition or parallel grouping of the successive crystals. Another kind is that which is illustrated by f. 295, 297, 311, where the successively reversed individuals are not parallel. In this case the axes may, however, lie in a zone, as the prismatic twins of. aragonite, or they may be inclined to each other, as in f. 311 , of staurolite. In all such cases where the repetition of the twinning tends to produce circular forms, as f .281 , of rutile, the number of individuals is equal to the number of times the angle between the two axial systems is contained in $360^{\circ}$. For example, five-fold twins occur in the tetrahedrons of gold and sphalerite, since $5 \times 70^{\circ} 32^{\prime}$ (the tetrahedral angle) $=360^{\circ}$ (approx.). A compound crystal, when there are three individuals, is called a Trilling (Drilling, Germ.), where there are four individuals, a Fourling (Vierling, Germ.), etc. (See also on p. 186.)
Compound crystals in which twinning exists in accordance with two laws at once are of rare occurrence; an excellent example is afforded by staurolite, f. 312. They have also been observed on albite (f. 333), orthoclase, chalcocite, and in other less distinct cases.

## Examples of different methods of Twinning.*

Isometric System.-With few exceptions the twins of this system are of one kind, the twinning axis an octahedral axis, and the twinning plane consequently an octahedral plane; in most cases also the latter coincides

with the composition-face. Fig. 263 shows this kind as applied to the simple octahedron, it is especially common with the spinel group of minerals; similarly, f. 269, a more complex form, and also, f. 270, a dodecahedron twinned ; all these are contact twins. Fig. 271 is a penetration twin following the same law; the twinning being repeated, and the form flattened parallel to an octahedral face. Fig. 266, p. 91 , shows a twin of

[^9]fluorite, two interpenetrating cubes; f. 272 exhibits a dodecahedral twin of sodalite occurring in nature of almost ideal symmetry, and f. 273 is a tetrahedral twin of the species tetrahedrite ; the same law is true for all.


Sodalite.

273


Tetrahedrite.


Haüynite.

Figs. 274, 275, 276, are twins whose axes are parallel ; these forms are possible only with hemihedral crystals. The twinning axis is here a dodecahedral axis and the twinning plane a dodecahedral plane. The same

## 275




Pyrite.

277


Magnetite.
method of composition is often seen in dendritic crystallizations of native gold and copper, in which the angle of divergence of the branches is $60^{\circ}$ and $120^{\circ}$, the interfacial angles of a dodecahedron. The brownish-black mineral in the mica from Pennsbury, Pa., is magnetite in this form (f. 277), as first observed by G. J. Brush.

Tetragonal System.-The most common method is that where the twin-ning-plane is parallel to $1-i$. It is especially characteristic of rutile and cassiterite. This is illustrated in f. 264 and similarly in f. 278. Fig. 268 shows a similar twin of rutile, and in f . 281 to 283 the twinning according to this law is repeated. In f. 281 the vertical axes of the succossive six individuals lie in a plane, and an enclosed circle is the result; in f. 282 the successive vertical axes form a zig-zag line ; there are here four individuals,
add four more behind, the last (VIII) uniting with the first (I), and let it be developed vertically, and the complex form produced results in the scalenohedron twin of f . 283. In chalcopyrite, the octahedron 1 , which is

very near a regular octahedron in angle, may be the twinning-plane, and forms are thus produced very similar to f. 263. With hemihedral forms twinning may take place as shown in f . 280 , where the axis of revolution

is a diagonal axis, and the plane of twinning the prism $I$. It is not always indicated by a re-entering angle, but is sometimes only shown by the obligue striations in two directions meeting in the line of contact.


Rutile.

284


Pyrrhotite.

Another mode of twinning is that occurring in leucite, observed by vom Rath, who showed the species to be tetragonal. The twinning-plane is here 2-i. ( ${ }^{\text {Tahrb. Min., 1873, 113.) }}$

Hexagonal System.-- In the holohedral division of this system twins are rare. An example is furnished by pyrrhotite, f. 284, where the twinningplane is the pyramid 1, the vertical axes of the individual crystals being nearly at right angles to each other ( $0 \wedge 1=135^{\circ} 8^{\prime}$ ). Another example is tridymite * (see p. 288), where the twinning-plane is either the pyramid 1 or $\frac{3}{4}$.


In the species of the rhombohedral division twins are numerous; the ordinary methods are the following: the twinning-plane the rhombohedron $R$, f. 285 ; the rhombohedron $-2 R$, f. 288 ; the rhombohedron $-\frac{1}{2} R$, f. 286. The last inentioned method is common in masses of calcite, where by its frequent repetition it gives rise to thin lamellæ; these are observed often in crystalline limestones. (See p. 173.)


The twinning-plane may also be the basal plane, the axis of revolution consequently the vertical axis. This is illustrated in f. 287, a complex penetration twin of chabazite, also f. 267 (hematite), and in f. 289, 290. It is also common with quartz, the two crystals sometimes distinct, and joined by a prismatic plane, sometimes interpenetrating each other very irregularly, as shown in f. 265.
 ingly common, and the variety of methods is very great. These may, how. ever, be brought into two groups, according as the twinning-plane is (1) a prismatic plane, vertical or horizontal, or (2) an octahedral plane. The twinning is very often repeated, and always in accordance with the law already stated, that the number of individuals is determined by the number of times that the angle of the two axial systems is contained in $360^{\circ}$
(a) Twinning parallel to a prism whose angle is approximately $120^{\circ}$.

1. Prism vertical.-The principal examples are aragonite, $I \wedge I=116^{\circ}$ $10^{\prime}$; cerussite, $I \wedge I=117^{\circ} 13^{\prime}$; witherite, $I \wedge I=118^{\circ} 30^{\prime}$; bromlite, $I \wedge I=118^{\circ} 50^{\prime}$; chalcocite, $I \wedge I=119^{\circ} 35^{\prime}$; stephanite, $I \wedge I=115^{\circ}$ $39^{\prime}$; dyscrasite, $I \wedge I=119^{\circ} 59^{\prime}$. Figs. 291, 292, represent twins of aragonite in accordance with this law. Figs. 293, 294, show cross-sections of the two prisms of the preceding figures, in the latter the form is hexagonal, though not regularly so. Fig. 295 is a cruciform twin of the same species.

2. Prism horizontal ; that is, a macrodome.-Examples: arsenopyrite, $1-\bar{\imath} \wedge 1-\bar{\imath}=120^{\circ} 46^{\prime}$; leadhillite, $1-\bar{\imath} \wedge 1-\bar{\imath}=119^{\circ} 20^{\prime}$;


Manganite. humite, type 1.
3. Prism horizontal ; that is, a brachydome.Examples: manganite, $1-\tau \wedge 1-\check{\imath}=122^{\circ} 50^{\gamma}$ (f. 296); chrysoberyl, $3-\imath^{\circ} \wedge 3-乞(f .300)=120^{\circ} 13^{\prime}$; colnmbite, $2-\check{\varkappa} \wedge 2-\check{\iota}=117^{\circ} 20^{\prime}$ 。

In all these cases there is a strong tendency toward repetition of the twinning, by which forms often stellate, sometimes apparently hexagonal, result. These forms are illustrated in the following figures : f. 297 is of witherite; f. 298 a crystal of leadhillite, in its twinned form of very rhombohedral aspect. Figs. 299 and 300 are both chrysoberyl, where $3-\check{6}$ is the twinning-plane; six-rayed twins are very common in this species.
The genesis of these forms is further illustrated by the following crose-
sections. Fig. 301 shows a cross-section of a cerussite twin, and f. 302 cne of the crystal of leadhillite figured above (f. 298).

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Witherite.

298


Leadhillite.

299


Chrysoberyl.


Chrysoberyl.

In f. 303 , three rhombic prisms, $I$, of aragonite, are combined about their acute angles, the dotted lines showing the outlines of the prisms, and the cross lining the direction of the brachydiagonal ; and in f. 304, four are similarly united. In f. 305, three similar prisms, $I$, are combined about the

obtuse angle. This twin combination may take the form of a hexagonal prism, with or without re-entering angles; of a three-rayed twin, like $f$. 301, and if a penetration-twin, of a composite prism, like f. 306 (the numbering of the parts showing the relation), or a six-rayed twin. In all these cases the stellate form depends on the extension of the individuals beyond the normal limits.
(b) Prismatic angle approximately that of the regular octahedron, $109^{\circ}$ $28^{\prime}$. An example is furnished by the species staurolite (f. 307), where th
twinning-plane is $i \frac{-3}{2}$, and the corresponding prismatic angle is $109^{\circ} 14^{4}$ (over $i-\check{\imath}$, or $70^{\circ} 46^{\prime}$ over $i-\bar{i}$ ).

(c) Prismatic angle approximately $90^{\circ}$. Another example is furnished by marcasite, whose prismatic angle is $106^{\circ} 5^{\prime}$. The twins are generally compound, the repetition with the twimningplane sometimes parallel, sometimes oblique, see p. 247 In f. 308 the compound crystal consists of five individuals, since five times $73^{\circ} 55^{\prime}$ is ap. proximately equal to $360^{\circ}$.
Examples are furnished by bournonite, $I \wedge I=91^{\circ} 12^{\prime}$, see p. 254 , and staurolite. In the latter case the twinning-plane is a brachydome, $\frac{3}{2}-\tau$, and the angle is $91^{\circ} 18^{\prime}$; the form is shown in f. 309, it being that of a nearly rectangular cross. See also phillipsite, p. 345.
2. The twinning-plane may be also an octahedral plane. An excellent example is furnished by staurolite, where the twinning-plane is $\frac{3}{2} \frac{3}{2}$ (f. 310). The crystals cross at angles of nearly $120^{\circ}$ and $60^{\circ}$, hence the form in f . 311 , consisting of three individuals (trilling) forming a six-rayed star. In f. 312 both this method of twinning and that mentioned above are com-

bined. There are thus for the species staurolite three methods of twinuing, parallel to $i-\frac{3}{2}$, to $\frac{3}{2}-t$, and to $\frac{3}{2}-\frac{3}{2}$. If the occurring prism is made $i-\frac{3}{2}$, then the three twinning-planes become $I, 1-\imath, 1$, or fundamental planes, as is usually true.

Monociunic system.-The following examples comprise the more commonly occurring methods of twinning in this system.
(a) The twinning-plane is the orthopinacoid ( $i-i$ ). This is true in the case of the common twins of orthoclase (f. 318), called the Carlsbad twine. The axis of revolution is normal to $i-i$ (see also p. 90), while the two erystals are united by the clinopinacoid, which is consequently the compo-sition-face. These twins may be either right- or left-handed (f. 318 or f. 319), according as the right or left half of the simple form (f. 317) has been reiolved.

Fig. 313, of pyroxene, is another familiar example; so also f. 314, of which f. 315 is the simple form. Fig. 320 is a twin of scolecite, where the twin structure is shown by the striations on the clinopinacoid.


A form of penetration-twin, with $i \cdot i$ the twinning-plane, is shown in f. 321 (from von Lang). The mode of combination and cross-penetration of the two crystals 1,2 , is illustrated in f .322 ; it is a medial section of f. 321 from front to back.
(b) The twinning-plane may also be the basal plane. This is common with orthoclase (f. 324); also with gypsum (f. 323). It has also been observed by the author in chondrodite, type II and III, from Brewster, N. Y., see p. 305 .
(c) Figs. 325, 326, 327 show another method of twinning of orthoclase parallel to the clinodome, $2-i$. These twins are peculiar in that


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Malachite. they form nearly rectangular prisms, since $O \wedge 2-i=135^{\circ} 3 \frac{1}{2^{\prime}}$. They are common among the orthoclase crystals from Baveno, and hence are called Baveno twins. This method of twinning is also common with the amazon-stone of Pike's Peak.

The union of four crystals of this kind produces the form sepresented in f. 325 ; and the same, by penetration, develops the penetration-twin of f. 327 (from v. Rath), which apparently consists of four pairs of twins, but may be regarded as made by the cross-penetration of the crystals of two pairs, or of the four of $f .325$.

Forms like f. 325 may have one of the four parts undeveloped and so consist of three united crystals, and also the other parts, as in such compound twins generally, may be very unequal.

Twins corresponding to those of the orthorhombic system, where the twinning-plane is a prism whose angle is nearly $120^{\circ}$, have been obserred by vom Rath in humite, types II and III.

Tricinicic system.-In the twins of the triclinic system, the three axea
may be axes of revolution, in which case the twinning-planes are not occurring erystallographic planes; or, the pinacoid planes may be the planes of twinning and the normals to them the axes of revolution. Some of the cases are illustrated in the following figures of albite. In f. 329 the brachy pinacoid $(i-\breve{ })$ is the twinning-plane; f. 328 is the same, but it is a penetration-twin; this is the most common method of twinning with this species.


In f. 332 the vertical axis is the twinning-axis. Fig. 333 (from G. Rose) is a double twin, the two halves of which are like f. 328, but they are twinned together like f. 332. It happens in albite that the plane angles

on $i-\ell$, made by the edges $I \wedge O$ and $I \wedge 1$ differ but $37^{\prime}$ (the former being $116^{\circ} 26^{\prime}$, the latter $115^{\circ} 55^{\prime}$ ), and hence it is that in the twin $O$ and 1 fal! nearly into one plane.

Composition parallel to $O$, where the revolution is on a horizontal axis normal to the shorter diagonal of $O$, is exemplified in f. 334 (from G. Rose). Both right- and left-handed twins of this kind occur; also double twins in which this method is comoined with twinning (like that in f. 329, 330), parallel to $i-\ell$.

A thorough discussion of the method of twinning in the triclinic system has been given by Schrauf in his monograph of the

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Albite. species brochantite (Ber. Ak., Wien, lxvii., 275, 1873).

## Regular Grouping of Crystals.

Connected with the subject of twin crystals is that of the parallel position of associated crystals of the same species, or of different species. Crystals of the same species occurring together are very commonly in parallel position. In this way large crystals are sometimes built up of smaller individuals grouped together with corresponding planes parallel. This parallel grouping is often seen in crystals as they lie on the supporting rock. On glancing the eye over a surface covered with crystals, a reflection from one face will often be accompanied with reflections from the corresponding face in each of the other crystals, showing that the crystals are throughout similar in their positions.

Crystals of different species often show the same tendency to parallelism in mutual position. This is true most frequently of species which, from similarity of form and composition, are said to be isomorphous (see p. 199). Crystals of albite, implanted on a surface of orthoclase, are sometimes an example of this; crystals of hornblende and pyroxene, and of various kinds of mica are also at times observed associated in parallel position.

The same relation of position also occasionally occurs where there is no connection in composition, as the crystals of rutile on tabular crystals of hematite, the vertical axes of the former coinciding with the lateral axes of the latter. Breithaupt has figured crystals of calcite, whose rhombo-

hedral faces $\left(-\frac{1}{2} R\right)$ had a series of quartz crystals upon them, all in parallel position (f. 335); and Frenzel and vom Rath have described the same association where three such quartz crystals, one on each rhombohedral face, entirely enveloped the calcite, and uniting with re-entering
angles formed pseudo-twins (rather trillings) of quartz afteı calcite. The anthor has described a similar occurrence from "Specimen Mountain," in the Yellowstone Park; the form is shown in f. 336. (Am. J. Sci, III, xii., 1876.)

## IRREGULARITIES OF CRYSTALS.

The laws of crystallization, when unmodified by extrinsic canses, should produce forms of exact symmetry; the angles being not only equal, but also the homologous faces of crystals and the dimensions in the directions of like axes. This symmetry is, however, so uncommon, that it can hardly be considered other than an ideal perfection. Crystals are very generally distorted, and often the fundamental forms are so completely disguised, that an intimate familiarity with the possible irregularities is required in order to unravel their complexities. Even the angles may occasionally vary rather widely.

The irregularities of crystals may be treated of under several heads: 1 , Imperfections of surface; 2, Variations of form and dimensions; 3, Variations of angles; 4, Internal imperfections and impurities.

## I. Imperfections in the Surfaces of Crystals.

1. Striations or angular elevations arising from oscillatory combinations. -The parallel lines or furrows on the surfaces of crystals are called strice, and such surfaces are said to be striateil.

Each little ridge on a striated surface is enclosed by two narrow planes more or less regular. These planes often correspond in position to different planes of the crystal, and we may suppose these ridges to have been formed by a continued oscillation in the operation of the causes that give rise, when acting uninterruptedly, to enlarged planes. By this means, the surfaces of a crystal are marked in parallel lines, with a succession of narrow planes meeting at an angle and constituting the ridges referred to.


Magnetite.

This combination of different planes in the formation of a surface has been termed oscillatory combination. The horizontal striæ on prismatic crystals of quartz are examples of this combination, in: which the oscillation has taken place between the prismatic and pyramidal planes. As the crystals lengthened, there was apparently a continual effort to assume the terminal pyramidal planes, which effort was interruptedly overcome by a strong tendency to an increase in the length of the prism. In this manner, crystals of quartz are often tapered to a point, without the usual pyramidal terminations.

Other examples are the striation on the cubic faces of pyrite parallel with the intersections of the cube with the planes of the pyritohedron; also the striations on magnetite (f. 337) due to the oscillation between the octahedron and dodecaliedron.

Prisms of tourmaline are very commonly bounded vertically by three convex surfaces, owing to an oscillatory combination of the planes $I$ and $i-2$.

Faces of crystals are often marked with angular elevations more or less distinct, due sometimes also to oscillatory combination. Octahedrons of fluorite are common which have for each face a surface of minute cubes, proceeding from an oscillation Letween the cube and octahedron. This is a common cause of drusy surfaces with the crystals of many minerals.
2. Striations from oscillatory composition.-The striations of the plane $O$ of albite and other triclinic feldspars, and of the rhombohedral surfaces some calcite, have been attributed, on p. 91, to oscillatory twinning.
3. Markings from erosion and other causes.-It is not uncominon that the faces of crystals are uneven, or have the crystalline structure developed as a consequence of etching by some chemical agent. Cubes of galenite are often thus uneven, and crystals of lead sulphate or lead carbonate are somerimes present as evideuce with regard to the cause. Crystals of numerous other species, even of corundum, spinel, quartz, etc., sometimes show the same result of partial change over the surface-often the incipient stage in a process tending to a final removal of the whole crystal. Interesting investigations have been made by various authors on the action of solvents on different minerals, the actual structure of the crystals being developed in this way. These are referred to again in another place (p. 122).

The markings on the surfaces of crystals are not, however, always to be ascribed to etching. In most cases etchings, as well as the minute angular elevations upon the planes, are a part of the original molecular growth of the crystal, and often serve to show the successive stages in its history. They are the imperfections arising from an interrupted or disturbed development of the form, the perfectly smooth and even crystalline faces being the result of completed action free from disturbing canses. Examples of the marking referred to occur on the crystals of most minerals, and conspicuously so on the pyramidal planes of quartz.

The development of this subject belongs rather to crystallogeny ; reference may, however, be made here to the memoirs of Scharff, bearing on this subject, especially one entitled "Ueber den Quarz, II., die Uebergangsflächen," Frankfort, 1874; also to the Crystallography of Sadebeck (for title see Introduction).

It follows from the symmetry of crystallization that like planes should be physically alike, that is in regard to their surface character; it thus often happens that on all the crystals of a species from a given locality, or perhaps from all localities, the same planes are etched or roughened alike. For example, on crystals of datolite from Bergen Hill, the plane $-2-i$ is almost uniformly destitute of lustre; there is much uniformity on the crystals of quartz in this respect.
4. Curved surfaces may result from (a) oscillatory combination; or (b) some independent molecular condition producing curvatures in the laminæ of the crystal; or (c) from a mechanical cause.

Curved surfaces of the first kind have been already mentioned, p. 102. A singular curvature of this nature is seen in f .339 , of calcite; and another in the same mineral in the lower part of f. 338 , in which traces of a scalenohedral form are apparent which was in oscillatory combination with the prismatic form.

Curvatures of the second kind sometimes have all the faces convex. This is the case in crystals of diamond (f. 340), some of which are almost spheres. The mode of curvature, in which all the faces are equally con vex, is less common than that in which a convex surface is opposite and parallel to a corresponding concave surface. Rhombohedrons of siderite (see p. 403) are usually thus curved. The feathery curves of frost on windows and the flagging stones of pavements in winter are other examples of curves of the second kind. The alabaster rosettes from the Mammoth Cave, Ky., are similar.


A third kind of curvature is of mechanical origin. In many species crystals appear as if they had been broken transversely into many pieces, a slight displacement of which has given a curved form to the prism. This is common in tourmaline and beryl. The beryls of Monroe, Conn., often present these interrupted curvatures, as represented in f. 341.

Crystals not unfrequently occur with a deep pyramidal depression occupying the place of each plane, as is often observed in common salt, alum, and sulphur. This is due in part to their rapid growth.

## II. Variations in the Forms and Dimensions of Crystals.

The simplest modification of form in crystals consists in a simple variation in length or breadth, without a disparity in similar secondary planes The distortion, however, extends very generally to the secondary planes, especially when the elongation of a crystal takes place in the direction of a diagonal, instead of the crystallographic axes. In many instances, one or more planes are obliterated by the enlargement of others, proving a scrirce of much perplexity to the student. The interfacial angles remain constant, unaffected by these variations in form. These changes in form often give rise to what is called by Sadebeck pseudo-symmetry; the distorted forms of one system appearing similar to the normal forms of another. (Compare the descriptions of the following figures.) As most of the difficulties in the
study of crystals arises from these distortions, this subect is one of great importance.

Figs. 342 to 353 represent examples from the isometric system.
A cube lengthened or shortened along one axis becomes a right square prism, and if varied in the direction of two axes is changed to a rectangular prism Cubes of pyrite, galenite, fluorite, etc., are generally thus distorted. at is very unusual to find a cubic crystal that is a true symmetrical cube. In some species the cube or octahedron (or other isometric form) is lengthened into a capillary crystal or needle, as happens in cuprite and pyrite.

An octahedron flattened parallel to a face, or in the direction of a trigonal interaxis, is reduced to a tabular crystal (f. 342). If lengthened in the same direction, it takes the form in f .343 ; or if still farther lengthened to the obliteration of $\mathrm{A}^{\prime}$, it becomes an acute rhombohedron (same figure).

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When an octahedron is extended in the direction of a line between two opposite edges, or that of a rhombic interaxis, it has the general form of a rectangular octahedron; and still farther extended, as in f. 344 , it is changed to a rhombic prism with dihedral summits (spinel, fluorite, magnetite). The figure represents this prism lying on its acute edge.
The dodecahedron lengthened in the direction of a diagonal between the

obtuse solid angles, that is, that of a trigonal interaxis, becomes a sixsided prism with three-sided summits, as in f .345 ; and shortened in the same direction is a short prism of the same kind (f. 346). Both resemble rhombohedral forms and are common in garnet and zinc blende. When lengthened in the direction of one of the cubic axes, it becomes a square prisin with pyramidal summits (f. 347), and shortened along the same axis is reduced to a square octahedron. with truncated baeal angles (f. 348).

The trapezohedron is still more disguised by its distortions. When elongated in the line of a trigonal interaxis, it assumes the form in f .349 ; and still farther lengthened, to the obliteration of some of the planes, becomes a scalene dodecahedron (f. 350). This has been observed in fluor spar. Only twelve planes are here present out of the twenty-four. Threads of native gold from Oregon, are strings of crystals presenting the form of a very acute rhombohedron, with the other planes of the trisoctahedron 3-3 (the pyramidal and terminal obtuse rhombohedral) quite small at the ex-tremities.-See Am. J. Sci., vol. xxxii., p. 133, 1886.

If the clongation of the trapezohedron takes place along a cubic axis, it becomes a double eight-sided pyramid with four-sided summits (f. 351); or if these summit planes are obliterated by a farther extension, it becomes a complete eight-sided double pyramid (f. 352).


A scaleno-dodecahedron of calcite is shown distorted in f .353 , which appears, however, to be an eight-sided prism, bounded laterally by the planes $R, 1^{3}, 1^{3}$, and $R$, and their opposites, and terminated by the remaining planes. The following figures of quartz (f. 354, 355) represent distorted forms of this mineral, in which some of the pyramidal faces by enlargement displace the prismatic faces, and nearly obliterate some of the other pyramidal faces; see also f. 336 .

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Calcite.

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Quartz.

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Quartz

Fig. 356 is a distorted crystal of apatite ; the same is shown in f. 357 with the normal symmetry. The planes between $O$ and the right $l$ are enlarged, while the corresponding planes below are in part obliterated.

By observing that similar planes are lettered alike, the correspondence of the two figures will be understood.

In deciphering the distorted crystalline forms it must be remembered that while the appearance of the crystals may be entirely altered, the angles remain the same ; moreover, like planes are physically alike, that is, alike in degree of lustre, in striations, and so on.


In addition to the variations in form which have just been described, stul greater irregularities are due to the fact that, in almost all cases, crystals in nature are attached either to other crystals or to some rock surface, and in consequence of this are only partially developed. Thus quartz crystals are generally attached by an extremity of the prism, and hence have only one set of pyramidal planes; perfectly formed crystals, as those from Herkimer Co., N. Y., having the double prramid complete, are rare. The same statement may be made for nearly all species.

## III. Variattons in the Anales of Crystals.

The greater part of the distortions described occasion no change in the interfacial angles of crystals. But those imperfections that produce convex, curved, or striated faces, necessarily cause such variations. Furthermore, circumstances of heat or pressure under which the crystals were formed may sometimes canse not only distortion in form, but also some rariation in angle. The presence of impurities at the time of crystallization may also have a like effect.

Still more important is the change in the angles of completed crystals which is caused by subsequent pressure on the matrix in which they were formed, as, for example, the change which may take place during the more or less complete metamorphism of the enclosing rock.

The change of composition resulting in pseudomorphous crystals (see p. 113) is generally accompanied by an irregular change of angle, so that the psendomorphs of a species vary much in angle.

In general it is safe to affirm that, with the exception of the irregularities
arising from imperfections in the process of crystallization, or from changes produced subsequently, variations in the angles are rare, and the constancy of angle alluded to on p. 87 is the universal law.*

In cases where a greater or less variation in angle has been observed in the crystals of the same species from different localities, the cause for this can usually be found in a difference of chemical composition. In the case of isomorphous compounds it is well known that an exchange of corresponding chemically equivalent elements may take place without a change of form, though usually accompanied with a slight variation in the fundamental angles.

The effect of heat upon the form of crystals is alluded to upon p. 168.

## IV. Internal Imperfections and Impurities.

The transparency of crystals is often destroyed by disturbed crystallization, or by impurities taken up from the solution during the process of crystallization. These impurities may be simply coloring ingredients, or they may be inclosed particles, fluid or solid, visible to the eye or under the microscope. The coloring ingredients may vary in the course of formation of the crystals, and thus layers of different colors result; the tourmaline crystals of Chesterfield, Mass., have a red centre and blue exterior ; others from Elba are sometimes light-green below and black at the extremity; many other examples might be given.

The subject of the fluid and solid inclosures in crystals is one to which much attention has been directed of late years. Attention was early called to its importance by Brewster, who described the presence of fluids in quartz, topaz, beryl, chrysolite, and other minerals. In later years the matter has been more thoroughly studied by Sorby, Zirkel, Vogelsang, Fischer, Rosenbusch, and many others. (See Literature, p. 111.)

Many crystals contain empty cavities; in others the cavities are filled sometimes with water, or with the salt solution in which the crystal was formed, and not infrequently, especially in the case of quartz, with liquid carbonic acid, as first proved by Vogelsang, and recently followed out by Hartley. These liquid inclosures are marked as such, in many cases, by the presence in the carity of a movable bubble.

The solid inclosures are almost infinite in their variety. Sometimes they are large and distinct, and can be referred to known mineral species, as the scales of hematite to which the peculiar character of aventurine feldspar is due. Magnetite is a very common impurity for many minerals, appearing, for example, in the Pennsbury mica; quartz is also often mechanically mixed, as in stanrolite and gmelinite. On the other hand, quartz crystals very commonly inclose foreign material, such as chlorite, tourmaline, rutile, hematite, asbestos, and many other minerals.

[^10]The inclosures may also consist of a heterogeneous mass of material ; as the granitic matter seen in orthoclase crystals in a porphyritic granite; or the feldspar, quartz, etc., sometimes inclosed in large coarse crystals of beryl, occurring in granite veins.

An interesting example of the inclosure of one mineral by another is afforded by the annexed figures of tourmaline, enveloping orthoclase (E. H. Williams, Am. J. Sci., III., xi., 273, 1876). Fig. 358 shows the crystal of tourmaline ; and cross-sections of it at the points indicated ( $a, b, c$ ) are given by f. $359,360,361$. The latter show that the feldspar increases in amount in the lower part of the crystal, the tourmaline being merely a thin shell. Similar specimens from the same locality (Port Henry, Essex Co., N. Y.) show that there is no necessary connection between the position of the tourmaline and that of the feldspar.

Similar occurrences are those of trapezohedrons of garnet, where the latter is a mere shell, enclosing
 calcite, or sometimes epidote. Analogous cases have been explained by some authors as being due to partial pseudomorph ism, the alteration progressing from the centre outward.


The microscopic crystals observed as inclosures may sometimes be referred to known species, but more generally their true nature is doubtful. The term microlites, proposed by Vogelsang, is often used to designate the

minute inclosed crystals; they are generally of needle-like form, some times quite irregular, and often very remarkable in their arrangement and groupings; some of them are exhibited in f. 367 and f. 368 , as explained
below. Trichite and belonite are names introduced by Zirkel ; the former name is derived from $\theta \rho / \xi$, hair, the forms, like that in f. 362, are common in obsidian. Where the minute individuals belong to known species they are called, for example, feldspar microlites, etc.

Crystallites is an analogous term which is intended by Vogelsang to cover those minute forms which have not the regular exterior form of crystals, but may be considered as intermediate between amorphous matter and true crystals. Some of the forms, figured by Vogelsang, are shown in f. 363 to 366 ; they are often observed in glassy volcanic rocks, and also in furnace slags. A series of names have been given to varieties of crystallites, such as globulites, margarites, etc.*

The microscopic inclosures may also be of an irregular glassy nature ; a kind that exists in crystals which have formed from a melted mass, as lavas or the slag of iron furnaces.
In general, it may be said that while the solid inclosures occur sometimes quite irregularly in the crystals, they are more generally arranged with some evident reference to the symmetry of the form, or planes of the crystals. Examples of this are shown in the following figures: f. 367 ex

hibits a crystal of augite, inclosing magnetite, feldspar and nephelite microlites, etc., and f. 368 shows a crystal of leucite, a species whose crystals very commonly inclose foreign matter. Fig. 369 shows a section of a crystal of calcite, containing pyrite.


## Andalusite.

Another striking example is afforded by andalusite, in which the inclosea impuritics are of considerable extent and remarkably arranged. Fig. 370 shows the successive parts of a single crystal, as dissected by B. Horsford

[^11]of Springfield, Mass.; 371, one of the four white portions; and 372, the central black portion.
$371 \quad 372$


## Literature.

Some of the most important works on the subject are referred to here, but for a complete list of the literature up to 1873, reference may be made to llosenbusch (see below).

Blum, Leonhard, Seyfert, and Söchting, die Einschlüsse von Mineralien in krystallisirten Mineralien. (Preisschrift.) Haarlem, 1854.
Brewoster. Many papers published mostly in the Philosophical Magazine, and the Edinburgh Phil. Journal, from 1822-1856.

Fischer. Kritische-microscopische mineralogische Studien. Freiburg in Br., 64 pp., 1869; 1te Fortsetzung, 64 pp., 1871 ; 2te Forts., 96 pp., 1873.

Kosmann. Ueber das Schillern und den Dichroismus des Hypersthens. Jahrb. Min., 1869, 368 (ibid. p. 532, 1871, p. 501).

Rosenbusch. Microscopische Physiographie der petrographisch wichtigen Mineralien. 395 pp., Leipzig, 1873.

Schrauf. Studien an der Mineralspecies Labradorit. Ber. Ak. Wien, lx., Dec., 1869.
Sorby. On the microscopical structure of crystals, indicating the origin of minerals and rocks. Q. J. Geol. Soc., xiv., 453, 1858, (and many other papers).

Sorby and Butler. On the structure of rubies, sapphires, diamonds, and some other minerals. Proc. Roy. Soc., No. 109, 1869.

Vogelsang. Die Krystalliten. 175 pp., Bonn, 1875.
Vogelsang and Geissler. Ueber die Natur der Flüssigkeitseinschlüsse in gewissen Minera• lien. Pogg. Ann., exxxvii., 56, 1869 (ibid. p. 257).

Zirlel. Die microscopische Beschaffenheit der Mineralien und Gesteine. 502 pp ., Leipzig, 1873.

## CRYSTALLINE AGGREGATES.

The greater part of the specimens or masses of minerals that occur, may be described as aggregations of imperfect crystals. Even those whose structure appears the most purely impalpable, and the most destitute internally of anything like crystallization, are probably composed of crystalline grains. Under the above head, consequently, are included all the remaining varieties of structure in the mineral kingdom.

The individuals composing imperfectly crystallized individuals, may be:

1. Columns, or fibres, in which case the structure is columnar.
2. Thin laminas, producing a lainellar structure.
3. Grains, constituting a granular structure.

## 1. Columnar Structure.

A mineral possesses a columnar structure when it is made up of slender columns or fibres. There are the following varieties of the columnar struc ture:

Fibrous: when the columns or fibres are parallel. Ex. gypsum, asbestua Fibrous minerals have often a silky lustre.

Reticulated: when the fibres or columns cross in various directions, and produce an appearance having some resemblance to a net.

Stellated or stellular: when they radiate from a centre in all directions, and produce star-like forms. Ex. stilbite, wavellite.

Radiated, divergent: when the crystals radiate from a centre, without producing stellar forms. Ex. quartz, stibnite.

## 2. Lamellar Structure.

The structure of a mineral is lamellar when it consists of plates or leaves. The laminæ may be curved or straight, and thus give rise to the curved lamellar, and straight lamellar structure. Ex. wollastonite (tabular spar), some varieties of gypsum, talc, etc. When the laminæ are thin and easily separable, the structure is said to be foliaceous. Mica is a striking example, and the term micaceous is often used to describe this kind of structure.

## 3. Granular Structure.

The particles in a granular structure differ much in size. When coarse, the mineral is described as coarsely granular ; when finc, finely granular ; and if not distinguishable by the naked eye, the structure is termed impalpable. Examples of the first may be observed in granular crystalline limestone, sometimes called saccharoidal ; of the second, in some varieties of hematite ; of the last, in chalcedony, opal, and other species.

The above terms are indefinite, but from necessity, as there is every degree of fineness of structure in the mineral species, from perfectly impalpable, through all possible shades, to the coarsest granular. The term phanero-crystalline has been used for varieties in which the grains are distinct, and crypto-crystalline, for those in which they are not discernible.

Granular minerals, when easily crumbled in the fingers, are said to be friable.

## 4. Imitative Shapes.

Reniform : kidncy shape. The structure may be radiating or concentric.
Botryoidal: consisting of a group of rounded prominences. The name is derived from the Greek $\beta$ oт $\rho v \varsigma$, a bunch of grapes. Ex. limonite, chalcedony.

Mammillary : resembling the botryoidal, but composed of larger prominences.

Globular : spherical or nearly so ; the globules may consist of radiating fibres or concentric coats. When attached, as they usually are, to the surface of a rock, they are described as implanted globules.

Nodular : in tuberose forms, or having irregular protuberances cyer the surface.

Amygdaloidal: almond-shaped, applied usually to a greenstone contain ing almond-shaped or sub-globular nodules.

Coralloidal: like coral, or consisting of interlaced flexuous branchings of a white color, as in some aragonite.

Dendritic : branching tree-like.
Mossy : like moss in form or appearance.
Filiform or Capillary: very slender and long, like a thread or hair : monsists ordinarily of a succession of minute crystals.

Acicular: slender and rigid like a needle.
Reticulated: net-like.
Drusy: closely covered with minute implanted crystals.
Stalactitic: when the mineral occurs in pendant columns, cylinders, or elongated cones.

Stalactites are produced by the percolation of water, holding mineral matter in solution, through the rocky roofs of caverns. The evaporation of the water produces a deposit of the mineral matter, and gradually forms a long pendant cylinder or cone. The internal structure may be imperfectly crystalline and granular, or may consist of fibres radiating from the central column, or there may be a broad cross-cleavage.

Common stalactites consist of calcium carbonate. Chalcedony, gibbsite, brown iron ore, and many other species, also present stalactitic forms.

The term amorphous is used when a mineral has not only no crystalline form or imitative shape, but also does not polarize the light even in its minute particles, and thus appears to be destitute wholly of a crystalline structure internally, as most opal. Such a structure is also called colloid or jelly. like, from the Greek for glue. Whether there is a total absence of crystalline structure in the molecules is a debated point. The word is from a privative, and $\mu$ ó $\phi \dot{\eta}$, shape.

## PSEUDOMORPHOUS CRYSTALS.

Every true mineral species has, when crystallized, a form peculiar to itself; occasionally, however, erystals are found that have the form, both as to angles and general habit, of a certain species, and yet differ from it entirely in chemical composition. Moreover it is often seen that, though in outward form complete crystals, in internal structure they are granular, or waxy, and have no regular cleavage.

Such crystals are called pseudomorphs, and their existence is explained by the assumption, often admitting of direct proof, that the original mineral has been changed into the new compound, or has disappeared through some agency, and its place been taken by another chemical compound to which the form does not belong.

Pseudomorphs have been classed under several heads.

1. Pseudomorphs by substitution.
2. Pseudomorphs by simple deposition, (a) incrustation or (b) infiltra. tion.
3. Pseudomorphs by alteration; and these may be altered
(a) without a change of composition, by paranorphism;
(b) by the loss of an ingredient;
(c) by the assumption of a foreign substance;
(d) by a partial exchange of constituents.
4. The first class of psendomorphs, by substitution, embrace those sases where there has been a gradual removal of the original material and a corresponding and simultaneous replacement of it by another, without, however, any chemical reaction between the two. A common example of this is a piece of fossilized wood, where the original fibre has been replaced entirely by silica. The first step in the process was the filling of all the pores and cavities by the silica in solntion, and then as the woody fibre by gradual decomposition disappeared, the silica further took its place. Other examples are quartz after fluorite, calcite, and many other species, cassiterite after orthoclase, etc.
5. Pseudomorphs by incrustation, form a less important class. Such are the crusts of quartz formed over fluorite. In most cases the removal of the original mineral has gone on simultaneonsly with the deposit of the second, so that the resulting psendomorph is properly one of substitution. In pseudomorphs by infiltration, a cavity made by the removal of a crystal has been filled by another mineral.
6. The third class of psendomorphs, by alteration, include a considerable proportion of the observed cases, of which the number is very large. Conclusive evidence of the change which has gone on is often furnished by a kernel of the original mineral in the centre of the altered crystal ; e.g., a kernel of cuprite in a psendomorphous octahedron of malachite; also of chrysolite in a psendomorphous crystal of serpentine; of corundum in fibrolite. or spinel (Genth).
(a) An example of paramorphism is furnished by the change of aragonite to calcite at a certain temperature; also the paramorphs of rutile after arkansite from Magnet Cove.
(b) An example of the pseudomorphs in which alteration is accompanied by a loss of ingredients is furnished by crystals of limonite in the form of siderite, the carbonic acid having been removed; so also calcite after gay-lussite ; native copper after cuprite.
(c) In the change of cuprite to malachite, e.g., the familiar crystals from Chessy, France, an instance is afforded of the assumption of an ingredient, viz., carbonic acid. Pseudomorphs of gypsum after anhydrite occur, where there has been an assumption of water.
(d) A partial exchange of constituents, in other words, a loss of one and gain of another, takes place in the change of feldspar to kaolin, in which the potash silicate disappears and water is taken up; psendomorphs of chlorite after garnet, pyromorphite after galenite, are other examples.

The chemical processes involved in such changes open a wide field for investigation, in which Bischof, Delesse and others have done much.

## SECTION I.-SUPPLEMENTARY CHAPTER.

## IMPROVEMENTS IN THE INSTRUMENTS FOR THE MEASUREMENT OF THE ANGLES OF CRYSTALS (see pp. 83-87).

Reflecting Goniometer.-A form of reflecting goniometer, well adapted for accurate measurements, and at the same time thoroughly practical, is shown in $\mathrm{f} .3 \% \mathrm{~A}$. It is made on the Babinet type, with a horizontal graduated circle; the instruments of the Mitscherlich type, alluded to on p. 86, having a vertical circle. The horizontal circle has many advantages, especially when it is desired to measure the angles of large crystals or those which are

$$
372 \mathrm{~A} .
$$


attached to a large piece of rock. This particular form of instrument here figured is made by R. Fuess,* in Berlin (Alte Jacobstrasse 108), and has

[^12]many improvements suggested by Websky (Zeitschr. Kryst., iv., 545, 1880. See also Liebisch, Bericht über die wissenschaftlichen Instrumente auf der Berliner Gewerbeausstellung im Jahre 1879, pp. 330-332).

The instrument stands on a tripod with leveling screws. The central axis, $o$, has within it a hollow axis, $b$, with which turns the plate, $d$, carrying the verniers and also the observing telescope, the upright support of which is shown at $B$. Within $b$ is a second hollow axis, $e$, which carries the graduated circle, $f$, above, and which is turned by the screw-head, $g$; the tangent screw, $\alpha$, serves as a fine adjustment for the observing telescope, $B$, the screw, $c$, being for this purpose raised so as to bind $b$ and $e$ together. The tangent screw, $\beta$, is a fine adjustment for the graduated circle. Again, within $e$ is the third axis, $h$, turned by the screw-head, $i$, and within $h$ is the central rod, $s$, which carries the support for the crystal, with the adjusting and centering contrivances mentioned below. The rod, $s$, can be raised or lowered by the screw, $h$, so as to bring the crystal to the proper height, that is up to the axis of the telescope ; when this has been accomplished, the clamp at $p$, turned by a set-key, binds $s$ to the axis, $h$. The movement of $h$ can take place independently of $g$, but after the crystal is ready for measurement these two axes are bound together by the set-screw, l. The signal telescope is supported at $C$, firmly attached to one of the legs of the tripod. The crystal is mounted on the plate, $u$, with wax, the plate is clamped by the screw, $v$. The centering apparatus consists of two slides at right angles to each other (one of these is shown in the figure) and the screw, $a$, which works it; the end of the other corresponding screw is seen at $a^{\prime}$. The adjusting arrangement consists of two cylindrical sections, one of them, $r$, shown in the figure, the other is at $r^{\prime}$; the cylinders have a common centre.

The circle is graduated to degrees and quarter degrees, and the vernier gives the readings to $30^{\prime \prime}$, but by estimate they can be obtained to $10^{\prime \prime}$. The signals provided are four in number, each in its own tube, to be inserted behind the collimator lens; these are : (1) the ordinary telescope with the hair cross, to be used in the case of the most perfect planes; (2) the commonly used signal,* proposed by Websky, consisting of two small opaque circles, whose distance apart can be adjusted by a screw between them; the light passing between these circles enters the tube in a form resembling a double concave lens; also (3) an adjustable slit ; and, finally, (4) a tube with a single round opening, very small. There are four observing telescopes of different angular breadth of field and magnifying power, and hence suitable for planes varying in size and in degree of polish. A Nicol prism is also added.

The methods to be employed, both in making the preliminary adjustments required by every instrument before it can be used, and in the actual measurement of the angles of crystals, have been described by Websky (l. c.) with a fullness and clearness which leaves nothing to be desired, and reference must be here made to this memoir.

Microscope-Goniometer of Hirschwald.-For the measurement of the angles of crystals whose planes are destitute of polish, Hirschwald has derised a "microscope-goniometer" (Jahrb. Min., 1879, 301, 539 ; 1880, i., 156.See also Liebisch, l. c., pp. 336, 37\%) ; the actual construction has been made by Fuess. The instrument consists of a Wollaston goniometer with a centering telescope and a vertical microscope. The principle upon which the use of the instrument is based is this: that a plane seen through a microscope

[^13]will be in focus over its entire extent only when the plane is exactly at right angles to the axis of the microscope. The microscope stands vertically above the crystal, and is supported on a double slide, which allows of its being moved parallel and perpendicular to the axis of the goniometer, so that it is possible to see successively every portion of a crystal face fastened to the goniometer, and at the proper focal distance. The slide perpendicular to the axis of the goniometer carries a vernier, so that the position of the microscope can be measured on the fixed scale to a half millimeter. The micrometer screw of the microscope is arranged so that the raising or lowering of the microscope can be measured to 0.004 mm . The spider line in the eye-piece, parallel to the axis of rotation of the goniometer, is so adjusted that when the slide just mentioned stands at the zero of its scale, it lies exactly in the vertical plane through the axis. The horizontal centering telescope is placed opposite the crystal support, and moves on a slide parallel to the axis of the graduated circle. Its spider lines are so adjusted that their centre exactly coincides with this axis. The apparatus for centering and adjusting the crystal consists of a vertical disk allowing of motion in any direction perpendicular to the axis of rotation, and a spherical segment moved by four arms (Petzval support). In use the edge of the two planes to be measured is brought by means of the spider line of the microscope parallel to the axis of rotation of the goniometer, and there centered, by means of the telescope, so that as the crystal is turned this edge remains in the centre of the spider line of the centering telescope ; then the two planes which form this edge are, by successive adjustments by help of the microscope, brought each successively into an exactly horizontal position as the circle is revolved. The angle (normal angle) between the two planes is obtained in the usual manner. Hirschwald calculates that, with a sufficiently delicate arrangement of lenses, for planes whose width is 5 mm ., the theoretical error of measurement is $2^{\prime} 40^{\prime \prime}$; for those with a width of 10 mm ., the error is only $1^{\prime}$. The improved support for the crystal is so arranged that when the edge is exactly adjusted and one of the two planes carefully placed with the microscope, the second plane must be for its whole extent in the proper position as soon as this is true for a single point of the plane.

Contact-lever Goniometer of Fuess.-Another form of goniometer has been invented by Fuess (see Liebisch, 1. c., pp. 337-339) which aims to accomplish the same end as that of Hirschwald the exact measurement of the angle between two unpolished surfaces -but in this case the adjustment is accom-
 plished by mechanical means. The essential arrangement is shown in f. 372b, 372c. It consists of a Wollaston goniometer, $G$, supported upon a perfectly even unpolished
glass plate, $A$. The contact-lever is carried by $B$, which rests on the glass plate by two pegs, 0 , and by the screw, $n$, with a graduated head turning in connection with the index, $y$. Two arms, $F F$. go down from $B$, carrying the nut in which the screw, $r$, turns; this screw moves $B$ in a direction at right angles to tie axis of the goniometer. The arm, $D$, contains the nut for the adjusting screw, $m$ (similar to $n$ ), which belongs immediately to the lever system. On the arm $C$ is attached the knife edge, $l$, which meets the edge, $c$, fastened to the arm, $i$; this arm, $i$,

372c.
 turns about $a$, and is supported by the screw, $m$. The adjustable ball, $b$, supported on $t$, is to be placed so that the ivory index rests with the least possible pressure on the crystal-face at $K$ (see also f. 372 c ). The contactlever, $E$, whose longer arm marks on the scale, $S$, lies between $l$ and $c$; its head, $d$, is so to be adjusted that the lever resting on the lower enge, $c$, has a slight excess of weight on the side of the goniometer, so that it touches both edges. A perceptible play of the long arm corresponds to a raising or lowering of the ivory index of 0.0005 mm . If the plane has a width of 1 mm ., the degree of accuracy attainable is theoretically $2^{\prime}$.

In the preliminary centering and adjusting the work is facilitated by the arrangement shown in f. 372d. It consists of a plate, $p$, which rests on $\Lambda$ by the three set-screws, $s$. Two arms, with set-screws, $t$, resting on the side of the supporting plate, make possible, similar to $r$, a movement parallel to this side. An index finger, $l$, is supported above the plate, $p$. The screws, $s$ and $t$, are now set so that the sharp edge of $l$ is exactly in the prolongation of the axis of rotation of the goniometer, which is necessarily parallel to the upper and side surfaces of the supporting plate. By the help of this arrangement, the approximate centering and adjusting of the crystal-edge can be readily accomplished, and also the parallelism between the crystal-face and the supporing plate be proved.

Measurement of the Angles of microscopic Crystals.-Bertrand (C. R., lxxxv., 1175, $187 \%$; Bull. Soc. Min., i., 22, 96, 18\%8) has described a method for obtaining the interfacial angles of microscopic crystals, which may be briefiy alluded to here. It is based on the geometrical principle that if the plane angles are known which the projections of a plane make with three perpendicular co-ordinate axes, the angular inclination of the plane to the three axes can be calculated. The crystal to be measured is fastened on a small cube of glass held in a pincer arrangement, on a secondary microscope stage ; this stage is, like the principal stage below it, movable about a vertical axis, and besides has by means of screws a motion in two perpendicular directions in a horizontal plane. The method of obtaining the desired angles is very ingenious, but too complex to allow of explanation here; reference must be made to the original paper. With crystals of from 1-20 to $1-30 \mathrm{~mm}$., Bertrand obtained results accurate within $6^{\prime}$, and he states that the method can be extended to crystals which have a magnitude of only $1-100 \mathrm{~mm}$.

## SECTION II.

## PHYSICAL CHARACTERS OF MINERALS.

The physical characters of minerals arc those which relate: I., tc Cohesion and Elasticity, that is: cleavage and fracture, hardness, and tenacity; II., to the Mass and Volume, the specific gravity ; III., to Light, the optical properties of erystals; also color, lustre, etc.; IV., to Heat; V., to Electricity and Magnetism; VI., to the action on the Senses, as taste, feel, etc.

## I. COHESION AND ELASTICITY.*

By cohesion is understood the attraction existing between the molecules of a body, in consequence of which they offer resistance to a force tending to separate them, as in breaking or scratching. This principle leads to some of the most universally important physical characters of minerals,cleavage, fracture, and hardness.

Elasticity, on the other hand, is the force which tends to bring the molecules of a body back in to their original position, from which they have been disturbed. Upon elasticity depends, for the most part, the degree of tenacity possessed by different minerals.

## A. Cleavage and Fracture.

1. Cleavage. - Most crystallized minerals have certain directions in which their cohesive power is weakest, and in which they consequently yield most readily to an exterior force. This tendency to break in the direction of certain planes is called cleavage, and being most intimately connected with the crystalline form it has already been necessary to define it, and to mention some of its most important features (p. 2). Cleavage differs (a) according to the ease with which it is obtained, and (b) according to its direction, crystallographically determined.
(a) Cleavage is called perfect or eminent when it is obtained with great ease, affording smooth, lustrous surfaces, as in mica, topaz, calcite. Inferior degrees of cleavage are spoken of as distinct, indistinct or imperfect, interrupted, in traces, difficult. These terms are sufficiently intelligible without further explanation. It may be noticed that the cleavage of a species is sometimes better developed in some of its varieties than in others.
(b) Cleavage is also named accending to the direction, crystallographically defined, which it takes in a species. When parallel to the basal section ( $O$ ) it is called basal, as in topaz; parallel to the prism, as in amphibole, it is called prismatic; also macrodiagonal, orthodiagonal, etc., when parallel to the several diametral sections; parallel to the faces of the cube, octa-

[^14]hedron, dodecahedron, or rhombohedron, it is called cubic, as galenite; octahedral, as fluorite; dodecahedral, as sphalerite; rhombohedral, as calcite.


#### Abstract

Intimately connected with the cleavage of crystallized minerals are the divisional planes investigated by Reusch (see Literature, p. 122). He has found that by pressure, or by a sudden blow, divisional planes are in many cases produced which are analogous to the cleavage planes. The first he calls Gleitfächen, or planes in which a sliding of the molecules upon each other takes place. Thus, for example, if two opposite dodecahedral edges of a cubic cleavage mass of rock-salt are regularly filed away, and the mass then subjected to pressure in this direction, a Gleitflüche is obtained parallel to the dodecahedral face.

The figures, on the other hand, obtained by a blow on a rounded steel point, placed perpendicular to the natural or cleavage face of a crystal, are called by him fracture-figures (Schlagfiguren). The divisional-planes in this case appear as cracks diverging from the point where the blow has been made. For instance, on a cubic face of rock-salt two planes, forming a rectangular cross, are obtained ; on biaxial mica, a six-rayed (sometimes three-rayed) star results from the blow, one ray of which is always parallel to the brachydiagonal axis of the prism.


2. Fracture.-The term fracture is used to define the form or kind of surface obtained by breaking in a direction other than that of the cleavage in crystallized minerals, and in any direction in massive minerals. When the cleavage is highly perfect in several directions, as the cubic cleavage of galenite, fracture is often not readily obtainable.

Fracture is defined as :
(a) Conchoidal; when a mineral breaks with curved concavities, more or less deep. It is so called from the resemblance of the concavity to the valve of a shell, from concha, a shell; flint.
(b) Even; when the surface of fracture, though rough, with numerous small elevations and depressions, still approximates to a plane surface.
(c) Uneven; when the surface is rough and entirely irregular.
(d) Huckley; when the elevations are sharp or jagged; broken iron.

Other terms also employed are earthy, splintery, etc.

## B. Hardness.

By the hardness of a mineral is understood the resistance which it offers to abrasion. The degree of hardness is determined by observing the ease or difficulty with which one mineral is scratched by another, or by a file or knife.

In minerals there are all grades of hardness, from that of a substance impressible by the finger-nail to that of the diamond. To give precision to the use of this character, a scale of hardness was introduced by Mors. It is as follows:

1. Talc ; common laminated light-green variety.
2. Gypsum ; a crystallizęd variety.
3. Calcite ; transparent variety.
4. F'luorite ; crystalline variety.
5. Apatite; transparent variety.
(5.5. Scapolite; crystalline variety.)
6. Feldspar (orthoclase); white cleavable variety.
7. Quartz; transparent.

## 8. Topaz; transparent.

9. Sapphire; cleavable varieties.
10. Diamond.

If the mineral under trial is scratched by the file or knife as easily as apatite, its hardness is called 5 ; if a little more easily than apatite and not so readily as fluorite, its hardness is called 4.5, etc. For minerals as hard or harder than quartz, the file will not answer, and the relative hardness is determined by finding by experiment whether the given mineral will scratch, or can be scratched by, the successive minerals in the scale.

It need hardly be added that great accuracy is not attainable by the above methods, though, indeed, for all mineralogical purposes exactness is quite unnecessary.

The interval between 2 and 3 , and 5 and 6 , in the scale of Mohs, being a little greater than between the other numbers, Breithaupt proposed a scale of twelve minerals; but the scale of Mohs is now universally accepted.

Accurate determinations of the hardness of minerals have been made by Frankenheim, Franz, Grailich and Pekarek, and others (see Literature, p. 122), with an instrument called a sclerometer. The mineral is placed on a movable carriage with the surface to be experimented upon horizontal; this is brought in contact with a steel point (or diamond-point), fixed on a support above; the weight is then determined which is just sufficient to move the carriage and produce a scratch on the surface of the mineral.

By means of such an instrument the hardness of the different faces of a given crystal has been determined in a variety of cases. It has been found that different planes of a crystal differ in hardness, and the same plane differs as it is scratched in different directions. In general, the hardest plane is that which is intersected by the plane of most complete cleavage. And of a single plane, which is intersected by cleavage planes, the direction perpendicular to the cleavage direction is the softer, those parallel to it the harder.

This subject has been recently investigated by Exner (p. 122), who has given the form of the curves of hardness for the different planes of many crystals. These curves are obtained as follows: the least weight required to scratch a crystalline surface in different directions, for each $10^{\circ}$ or $15^{\circ}$, from $0^{\circ}$ to $180^{\circ}$, is determined with the sclerometer; these directions are laid off as radii from a centre, and the length of each is made proportional to the weight fixed by experiment, that is, to the hardness thus determined; the line connecting the extremities of these radii is the curve of hardness for the given plane.

## C. Tenacity.

Solid minerals may be either brittle, sectile, malleable, flexible, or elastic. (a) Brittle; when parts of a mineral separate in powder or grains on attempting to cut it ; calcite.
(b) Sectile; when pieces may be cut off with a knife without falling to powder, but still the mineral pulverizes under a haumer. This character is intermediate between brittle and malleable; gypsum.
(c) Malleable; when slices may be cut off, and these slices flattened out mider a hammer ; native gold, native silver.
(d) Flexible; when the mineral will bend, and remain bent after the bending force is removed; talc.
(e) L'lustic ; when after being bent, it will spring back to its original position ; mica.

The elasticity of erystallized minerals is a subject of theoretical rather than practical importance. The subject has been acoustically investigated by Savart with very interesting results. Reference may also be made te the investigations of Neumann, and later those of Voigt and Groth. The must important principle established by these researches is, as stated by Groth, that in crystals the elasticity (coefficient of elasticity) differs in different directions, but is the same in all directions which are crystallographically identical; hence he gives as the definition of a crystal, a solid in which the elasticity is a function of the direction.

Intimately connected with the general subjects here considered, of cohesion in relation to minerals, are the figures produced by etching on crystalline faces (Aetzfiguren, Germ.), investigated by Leydolt, and later by Baumhauer, Exner, and others. This method of investigation is of high importance as revealing the molecular structure of the crystal ; reference, however, must be made to the original memoirs, whose titles are given below, for the full discussion of the subjeot.

The etching is performed mostly by solvents, as water in some cases, more gencrally the ordinary mineral acids, or caustic alkalies, also by steam and hydrofluoric acid; the latter is especially powerful in its action. The figures produced are in the majority of cases angular depressions, such as low triangular, or quadrilateral pyramids, whose outlines run parallel to some of the crystalline edges. In some cases the planes produced can be referred to occurring crystallographic planes. They appear alike on similar planes of crystals, and hence serve to distinguish different forms, perhaps in appearance identical, as the two sets of planes in the ordinary double pyramid of quartz; so, too, they reveal the compound twinning structare common on some crystals, as quartz (p. 89) and aragonite.
Analogous to the etching-figures are the figures produced on the faces of some crystals by the loss of water (Verwitterungsfiguren, Germ.) This subject has been investigated by Pape (see below).

## Literature.

## Cohesion; Hardness.

Frankenheim. De Crystalloruın Cohæsione, 1829; also in Baumgartner's Zeitschrift für Physik, ix., 94, 194. 1831.

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Hranz. Ueber die Härte der Mineralien und ein neues Verfahren dieselbe zu messen; Pogg. 1xxx., 37. 1850.
Grailich und Pekárek. Ber. Ak. Wien, xiii., 410. 1854.
Exner. Ueber die Härte der Krystallfächen; 166 pp. Wien, 1873.

## Elasticity.

Savart. Pogg. Ann., xvi., 206.
Neumann. Pogg. Ann., xxxi., 177.
Voigt. Pogg. Ann. Erg. Bd., vii, i, 177, $18 \%$.
Groth. Pogg. Ann., clvii., 115, 787. 1876.
Bauer. Untersuchung über den Glimmer und verwandte Minerale; Pogg. cxxxviii., 337, 1869.

Reusch. Ueber die Körnerprobe am Steinsalz n. Kalkspath. Pogg. cxxxii., 441, 1867; am zwei-axigen Glimmer, Pogg. Ann. cxxxvi, 430, 632 ;-am krystallirten Gyps, ibid., p. 135.

[^15]
## II. SPECIFIC GRAVITY.*

The specific gravity of a mineral is its weight compared with that of another substance of equal volume, whose gravity is taken at unity. In the case of solids or liquids, this comparison is usually made with water. If a cubic inch of any mineral weighs twice as much as a cubic inch of water (water being the unit), its specific gravity is 2 , if three times as much, ita specific gravity is 3 , etc.

The direct comparison by weight of a certain volume of wwater with an equal volume of a given solid is not often practicable. By making use, however, of a familiar principle in hydrostatics, viz., that the weight lost by a solid imınersed in water is equal to the weight of an equal volume of water, that is of the volume of water it displaces,--the determination of the specific gravity becomes a very simple process.

The weight of the solid out of water $(w)$ is determined by weighing in the usual mamer; then the weight in water is found $\left(w^{\prime}\right)$, when the loss by immersion or the difference of the two weights $\left(w-w^{\prime}\right)$ is the weight of a volume of water equal to that of the solid; finally the quotient of the first weight $(w)$ by that of the equal volume of water as determined $\left(w-w^{\prime}\right)$ is the specific gravity $(G)$.

Hence,

$$
G=\frac{w}{w-w^{\prime}} .
$$

For example, the weight of a fragment of quartz is found to be 4.534 grains. Its weight in water $=2.817$ grains, and therefore the loss of weight, or the weight of an equal volume of water $=1.717$. Consequently the specific gravity is equal to $\frac{4.534}{1.717}$, or 2.641 .

The ordinary method for obtaining the specific gravity of firm, solid minerals is first to weigh the specimen accurately on a good chemical balance, then suspend it from one pan of the balance by a horse-hair, silk thread, or better still by a fine platinum wire, in a glass of water conveniently placed beneath. The platinum wire may be wound around the specimen, or where the latter is small it may be made at one end into a little spiral support. While thus suspended, the weight is again taken with the same care as before.

The water employed for this purpose should be distilled, to free it from all foreign substances. Since the density of water varies with its temperature, a particular temperature has to be selected for these experiments, in
order to obtain uniform results: $60^{\circ} \mathrm{F}$. is the most convenient, and has been generally adopted. But the temperature of the maximum density of water, $39.2^{\circ}$ F. $\left(4^{\circ} \mathrm{C}.\right)$, has been recommended as preferable. For minerals soluble in water some other liquid. as alcohol, benzene, etc., must be employed, whose specific gravity (g) is accurately known; from the comparison with it, the specific gravity $(G)$ of the mincral as referred to water is determined, as by the formula:

$$
G=\frac{w}{w-w^{\prime}} g
$$


#### Abstract

A very convenient form of balance is the spiral balance of Jolly, where the weight is mea. sured by the torsion of a spiral brass wire. The readings, which give the weight of the mineral in and out of water, are obtained by observing the coincidence of the index with its image reflected in the mirror on which the graduation is made.

A form of balance in which weights are also dispensed with, the specific gravity being read off from a scale without calculation, has recently been described by Parish (Am. J. Sci., III., x., 352). Where great accuracy is not required, it can be very conveniently used.


If the mineral is not solid, but pulverulent or porous, it is best to reduce it to a powder ar.d weigh it in a little glass bottle (f. 373)
 called a pygnometer. This bottle has a stopper which fits tightly and ends in a tube with a very fine opening. The bottle is filled with distilled water, the stopper inserted, and the overflowing water carefully removed with a soft cloth. It is now weighed, and also the mineral whose density is to be determined. The stopper is then removed and the mineral in powder or in small fragments inserted, with care, so as not to introduce air-bubbles. The water which overflows on replacing the stopper is the amount of water displaced by the mineral. The weight of the pygnometer with the enclosed mineral is determined, and the weight of the water lost is obviously the difference between this last weight and that of the bottle and mineral together, as first determined. The specific gravity of the mineral is equal to its weight alone divided by the weight of the equal volume of water thas determined.

Where this method is followed with sufficient care, especially avoiding any change of temperature in the water, the results are quite accurate. Other methods of determining the specific gravity will be found described in the literature notices which follow.

It has been shown by Rose that chemical precipitates have uniformly a higher density than belongs to the same substance in a less finely divided state. This increase of density also characterizes, though to a less extent, a mineral in a fine state of mechanical subdivision. This is explained by the condensation of the water on the surface of the powder:

It may also be mentioned that the density of many substances is altered by fusion. The same mineral in different states of molecular aggregation may differ somewhat in density. Furthermore, minerals having the same cheinical composition have sometimes different densities corresponding $\omega$ the different crystalline forms in which they appear (see p. 199).

For all minerals in a state of average purity the specific gravi:y is one of the most important and constant characteristics, as urged especially by Breithaupt. Every chemical analysis of a mineral should be accompanied by a careful determination of its density.


#### Abstract

Practical suggestions.-The fragment taken should not be too large, say from two to five grams for ordinary cases, varying somewhat with the density of the mineral. The substance must be free from impurities, internal and external, and not porous. Care must be taken to exclude air-bubbles, and it will often be found well to moisten the surface of the specimen before inserting it in the water, and sometimes boiling is necessary to free it from air. If it absorbs water this latter process must be allowed to go on till the substance is fully saturated. No accurate determinations can be made unless the changes of temperature are rigorously excluded and the actual temperature noted.

In a mechanical mixture of two constituents in known proportions, when the specific gravity of the whole and of one are known, that of the other can be readily obtained. This method is often important in the study of rocks.


## Literature.-Speciptc Gravity.

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Tschermak. Ber. Ak. Wien, 292, 1863.
Websky. Die Mineralien nach den für das specifische Gewicht derselben angenommenen und gefundenen Werthen; 170 pp. Breslau, 1868.


## III. LIGHT.*

Before considering the distinguishing optical properties of crystals of the different systems, it is desirable to review briefly some of the more important principles of optics upon which the phenomena in question depend.

Nature of light.-In accordance with the undulatory theory of Huy. ghens, as further developed by Young and Fresnel, light is conceived to consist in the vibrations, transverse to the direction of propagation, of the particles of imponderable, elastic ether, which it is assumed pervades all space as well as all material bridies. These vibrations are propagated with great velocity in straight lines and in all directions from the luminous print, and the sensation which they produce on the nerves of the eye is called light.

The nature of the vibrations will be understood from f. 374. If $A B$ represents the direction of propagation of the light-ray, each particle of ether vibrates at right angles to this as a line of equilibrium. The vibra-

[^16]tion of the first particle induces a similar movement in the adjacent particle ; this is commmicated to the next, and so on. The particles vibrate successively from the line $A B$ to a distance corresponding to $b b^{\prime}$, called the amplitute of the vibration, then return to $b$ and pass on to $b^{\prime \prime}$, and so

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on. Thus at a given instant there are particles occupying all positions, from that of the extreme distance $b^{\prime}$, or $c^{\prime}$, from the line of equilibrium to that on this line. In this way the wave of vibration moves forward, while the motion of the particles is only transverse. In the figure the vibrations are represented in one plane only, but in ordinary light they take place in all directions about the line $A B$. The distance between any two particles, which are in like positions, of like phase, as $b^{\prime}$ and $c^{\prime}$, is called the wavelength ; and the time required for this completed movement is called the time of vibration. The intensity of the light varies with the amplitude of the vibrations, and the color depends upon the length of the waves; the wave-lengths of the violet rays are shorter than those of the red rays.

Two waves of like phase, propagated in the same direction and of equal intensity, on meeting unite to form a wave of double intensity (donble amplitude). If the waves differ in phase by half a wave-length, or an odd multiple of this, they interfere and extinguish each other. For other relations of phase they are also said to interfere, forming a new resultant wave, differing in phase and amplitude from each of the component waves; if they are waves of white light, their interference is indicated by the appearance of the successive colors of the spectrum. The propagation of the vibration-waves of light is sometimes compared to the effect produced when a pebble is thrown in a sheet of quiet water-a series of concentric circular waves are sent out from the point of agitation. These waves consist in the transverse vibration of the priclices of water, the waves move forward, but the water simply vibrates to and fro vertically.

The waves of light are propagated forward, in an analogous manner, in all directions from the luminous point, and the surface which contains all the particles which commence their vibrations simultaneously is called the wave-surface (Wellenfäche, Germ.).

If the propagation of light goes on with the same velocity in all directions in a homogeneous medium, the wave-surface is obviously that of a sphere and the medium is said to be isotrope. If it takes place with different velocities in different directions in a body, the wave-surface is sometimes an ellipsoid, but never spherical, as is shown later; such a lody is called anisotrope.

All the phenomena of optics are explained upon the supposition of waves of light, whose change of direction accompanies refraction, whose interference produces the colored bands of the diffraction spectra, etc. For the full discussion of the subject reference must be made to works on optics.

Refraction.-A ray of light passing through a homngeneous medium is always propagated in a straight line without deviation. When, however, the light-ray passes from one medium to another, which is of different density, it suffers a change of direction, which is called refraction. For instance, in f .375 , if $c a$ is a ray of light passing from air into water, its path will be changed after passing the surface at $a$, and it will continue in the direction $a b$. Conversely, if a ray of light, $b a$, pass from the denser medium, water, into the rarer medimm, air, at $a$, it will take the direction $a c$.

If now mao is a perpendicular to the surface at $a$, it will be seen that the angle cam, called the angle of incidence ( $i$ ) of the ray $c a$ is greater than the angle $b a o$, called the angle of refraction ( $r$ ), and what is observed in this case is found to be universally true, and the law is expressed as follows:

A ray of light in passing from a rarer
 to a denser medium is refracted towards the perpendicular ; if from 'a denser to a rarer medium it is refracted away from the perpendicular.

A further relation has also been established by experiment: however great or small the angle of incidence, cam (i), may be, there is always a constant relation between it and the angle of refraction, gam ( $r$ ), for two given substances, as here for air and water. This is seen in the figure where $a f$ and $d a$ are the sines of the two angles, and their ratio ( $=\frac{4}{3}$ nearly) is the same as that of the sine of any other angle of incidence to the sine of its angle of refraction. This principle is expressed as follows:

The sine of the angle of incidence bears a constaint ratio to the sine of the angle of refraction.

This constant ratio between these two angles is called the index of refraction, or simply $n$. In the example given for air and water $\frac{\sin i}{\sin r}=1.30 .5$, and consequently the value of the index of refraction, or $n$, is 1.335 .

The following table includes the values of $n$ for a variety of substances. For all crystallized minerals, except those of the isometric system, the index of refraction has more than one value, as is explained in the pages which follow.

| Ice | 1.308 | Calcite | 1.654 |
| :---: | :---: | :---: | :---: |
| Water | 1.335 | Aragonit | 1.693 |
| Fluorite | 1.436 | Boracite. | 1.701 |
| Alum. | 1.457 | Garnet. | 1.815 |
| Chalcedony. | 1.553 | Zircon | 1.961 |
| Rock-salt. | 1.557 | Blende. | 2.260 |
| Quartz. | 1.548. | Diamond | 2.419 |

In the principle which has been stated, $\frac{\sin i}{\sin r}=n$, twe points are to be
noted. First, if the angle $i=0^{\circ}$, then $\sin i=0$, and obviously also $r=0$. i: other words, when the ray of light coincides with the perpendicular no refraction takes place, the ray proceeding onward into the second medium without deviation.

Again, if the angle $i=90^{\circ}$, then $\sin i=1$, and the equation above becomes $\frac{1}{\sin r}=n$, or $\sin r=\frac{1}{n}$. As $n$ has a fixed value for every substance, it is obvious that there will also be a corresponding value of the angle $r$ for the case mentioned. From the above table it is seen that for water $\sin r=\frac{1}{1.3355^{\prime}}$, and $r=48^{\circ} 35^{\prime}$; for diamond, $\sin r=\frac{1}{2.42}$, and $r=24^{\circ} 25^{\prime}$.

In the example employed above, if the angle $b a o(r)=48^{\circ} 35^{\prime}$, the line $a c$ will coincide with $a f$, supposing the light to go from $b$ to $a$. If $r$ is greater than $48^{\circ} 35^{\prime}$, the ray no longer passes from the water into the air, but suffers total reflection at the surface $a$. This value of $r$ is said to be the limiting value for the given substance. The smaller it is the greater the amount of light reflected, and the greater the apparent brilliancy of the substance in question. This is the explanation of the brilliancy of the diamond.

Determination of the index of refraction.*-By means of a prism, as
 $M N P$ in f. 376, it is possible to determine the value of $n$, or index of refraction of a given substance. The full explanation of this subject belongs to works on optics, but a word is devoted to it here. If the material is solid, a prism must be cut and polished, with its edge in the proper direction, and having not too small an angle. If the refractive index of a liquid is required, it is placed within a hollow prism, with sides of plates of glass having both surfaces parallel.

The angle of the prism, $M N P(a)$, is, in each case, measured in the same manner as the angle between two planes of a crystal, and then the minimum anount of deviation ( $\delta$ ) of a monochromatic ray of light passing from a slit through the prism is also determined. The amount of deviation of a ray in passing through the prism varies with its position, but when the prism is so placed that the ray makes equal angles with the sides of the prism ( $i=i^{\prime}, f .376$ ), both when entering and emerging, this deviation has a fixed minimum value.

If $\delta=$ the minimum deviation of the ray, and

$$
a=\text { the angle of the prism, then } n=\frac{\sin \frac{1}{2}(a+\delta)}{\sin \frac{1}{2} \alpha}
$$

In determining the value of $n$ for different colors, it is desirable to emplny rays of known position in the spectrum.

Double refraction. -Hitherto the existence of only one refracted ray has been assumed when light passes from one medium to another. But it is a well-known fact that there are sometimes two refracted rays. The most familiar example of this is furnished by the mineral calcite, also called on account of this property "doubly-refracting spar."

If mnop (f. 377) be a cleavage piece of calcite. and a ray of light meet
it at $b$, it will, in passing through, be divided into two rays, $b c$, $b u$ Similarly a line seen through a piece of calcite ordinarily appears double.

It will be seen, however, that the same property is enjoyed by the great majority of crystallized minerals, though in a less striking degree.

Reflection.-When a ray of light passes from one medium to another, for example, from air to a denser substance, as has been illustrated, the light will be par-
 tially transmitted and refracted by the latter, in the manner illustrated, but a portion of it (the ray $a g$, in f. 375), is always reflected back into the air. The direction of the reflected ray is known in accordance with the following law:

The angles of incidence and reflection are equal.-In f. 375 the angle cam is equal to the angle mag.
The relative amount of light reflected and transmitted depends upon the angle of incidence, and also upon the transparency of the second medium. If the surface of the latter is not perfectly polished, diffuse reflection will take place, and there will be no distinct reflected ray.
Still another important principle, in relation to the same subject, remaine to be enunciated: The rays of incidence, reflection, and refraction in the same plane.

Dispersion.-Thus far the change in direction which a ray of light on refraction has alone been considered. It is also true that the of refraction differs for the different colors of which ordinary whi is composed, being greater for blue than for red. In consequence fact, if a ray of ordinary light pass through a prism, as in f .376 , wo win not only be refracted, but it will also be separated into its component colors, thus forming the spectrum.

This variation for the different colors depends directly upon their wavelengths; the red rays have longer waves, and vibrate more slowly, and hence suffer less refraction than the violet rays, for which the wave-lengths are shorter and the velocity greater.

Interference of light; diffraction. -When a ray of monochromatic light is made to pass through a narrow slity or by the edge of an opaque body it is diffracted, and there arise, as may be observed upon an appropriately placed screen, a series of dark and light bands, growing faiuter on the outer limits. Their presence, as has been intimated, is explained in accordance with the undulatory theory of light, as due to the interference, or mutual reaction of the adjoining waves of light. If ordinary light is employed, the phenomena are the same and for the same causes, except that the bands are successive spectra. Diffraction gratings, consisting of a series of extremely fine lines very closely ruled upon glass, are employed for the same purpose as the prism to produce the colored spectrum. The familias phenomena of the colors of thin plates and of Newton's rings depend upor the same principle of the interference of the light waves. This subject is one of the highest importance in its connection with the optical propertie of crystals, since the phenomena observed when they are viewed, undecertain circumstances, in polarized light are explained in an analngou manner. (Compare the colored plate, frontispiece.)

Polarization by reflection.-By polarization is understood, in general, that change in the character of reflected or transmitted light which diminishes its power of being further reflected or transmitted. In accordance with the undulatory theory of light a ray of polarized light is one whose vibrations take place in a single plane only.
Suppose (f. 378) $m n$ and op to be two parallel mirrors, say simple polished pieces of black glass; a ray of light, $A B$,
 will be reflected from $m n$ in the direction $B C$, and meeting op, will be again reflected to $D$. When, as here, the two mirrors are in a parallel position, the plane of reffection is clearly the same for both, the angles of incidence are equal, and the rays $A B$ and $C D$ are parallel. The ray $C^{C} D$ is polarized, although this does not show itself to the eye direct.

Now let the mirror, $o p$, be revolved about $B C$ as an axis, and let its position otherwise be unchanged, so that the angles of incidence still remain equal, it will be found that the reflected ray, $C^{\prime} D$, loses more and more of its brilliancy as the revolution continues, and when the mirror, $o p$, occupies a position at right angles to its Former position, the amount of light reflected will be a minimum, the lanes of reflection being in the two cases perpendicular to one another.
If the revolution of the mirror be continued with the sane conditions as bcfore, and in the same direction, the reflected ray will become brighter and brighter till the mirror has the position indicated by the dotted line, $0^{\prime} p^{\prime}$, when the planes of reflection again coincide, and the reflected ray, $C^{\prime} D^{\prime}$, is equal in brilliancy to that previously obtained for the position $C D$.

The same diminution to a ininimum will be seen if the revolution is continued $90^{\circ}$ farther, and the reflected ray again becomes as brilliant as before when the mirror resumes its first position op.

In the above description it was asserted that, when the planes of incidence of the mirrors were at right'angles to each other, the amount of light reflected would be less than in any other position, that is a minimum. For one sitgle position of the mirrors, however, as they thus stand perpendicular to each other, that is for one single value of the angle of incidence, the light will be practically extinguished, and no reflected ray will appear from the second mirror.

The angle of incidence, $A B H$, for this case is called the angle of polarization, and its value varies for different substances. It was shown further by Brewster that:

The angle of polarization is that angle whose tangent is the index of refraction of the reflecting substance, $i . e ., \tan i=n$.
Exactly the same phases of change would have been observed if the apleer mirror had been revolved in a similar manner. The first mirror is often called the polarizer, the second the analyzer.

This change which the light suffers in this case, ir consequence of reflection, is called polarization.

In order to give a partial explanation of this phenomenon and to make
the same subject intelligible as applied to other cases in which polarization occurs, reference must be made to the commonly received theory of the nature of light already defined.

The phenomena of light are explained, as has been stated, on the assumption that it consists of the vibrations of the ether, the vibrations being transverse, that is in a plane perpendicular, to the direction in which the light is propagated. These vibrations in ordinary light take place in all directions in this plane at sensibly the same time ; strictly speaking, the vibrations are considered as being always transverse, but their directions are constantly and instantaneously changing in azimuth. Such a ray of light is alike on all sides or all around the line of propagation, $A B, \mathrm{f} .374$. A ray of completely polarized light, on the other hand, has vibrations in one direction only, that is in a single plane.

These principles may be applied to the case of reflection already described. The ray of ordinary light, $A B$, has its vibrations sensibly simultaneous in all directions in the plane at right angles to its line of propagation, while the light reflected from each mirror has only those vibrations which are in one direction, at right angles to the plane of reflectionsupposing that the mirrors are so placed that the angle of incidence ( $A B H$ ) is also the angle of polarization.

If the mirror occupy the position represented in f .378 , the ray of light, $B C$, after being reflected by the first mirror, $m n$, contains that part of the vibrations whuse direction is normal to its plane of reflection called the plane of polarizutuon. This is also true of the second mirror, and when they are parallel and their planes of reflection coincide, the ray of light is rellected a second time without additional change.

If, however, the second mirror is revolved in the way described (p.130), less and less of the light will be reflected by it, since a successively smaller part of the vibrations of the ray $B C$ take place in a direction normal to its plane of reflection. And when the mirrors are at right angles to each sther, after a revolution of op $90^{\circ}$ about the line $B C$ as an axis, no part of the vibrations of the ray $B C^{\prime}$ are in the plane at right angles to the reflec-tion-plane of the second mirror, and hence the light is extinguished.

By reference to f. 375 this subject may be explained a little more broadly. It was seen that of the ray $c a$, meeting the surface of the water at $a$, part is reflected and part transmitted in accordance with the laws of reflection and refraction. It has been shown further that the reflected ray is polarized, that is, it is changed so that the vibrations of the light take place in one direction, at right angles to the plane of incidence. It is also true that the refracted ray is polarized, it containing only those vibrations which were lost in the reflected ray, that is, those which coincide with the plane of incidence and reflection.

It was stated that the vibrations of the polarized reflected ray take place at right angles to the plane of polarization. This is the assumption which is cominonly made; but all the phenomena of polarization can be equally well explained upon the other supposition that they coincide with this plane.

The separation of the ray of ordinary light into two rays, one reflected the other refracted, ribrating at right angles to each cther, takes place most s:umpletely when the reflected and refracted rays are $90^{\circ}$ from one another,
as proved by Brewster. From this fact follows the law arready stated, that the tangent of the angle of polarization is equal to the index of refraction. The angle of polarization for glass is about $54^{\circ} 35^{\prime}$.

This separation is in no case absolutely complete, but varies with different substances. In the case of opaque substances the vibrations belonging to the refracted ray are more or less completely absorbed (compare remarks on color, p. 168). Metallic surfaces polarize the light very slightly.

Polarization by means of thin plates of glass.-It has been explained that the light which has been transmitted and refracted is always at least in part polarized. It will be readily understood from this fact that when a number of glass plates are placed together, the light which passes through them all will be more and more completely polarized as their number is increased. This is a second convenient method of obtaining polarized light.

Polarization by means of tourmaline plates.-The phenomena of polarized light may also be shown by means of tourmaline plates. If from a crystal of tourmaline, which is suitably transparent, two sections be obtained, each cut parallel to the vertical axis, it will be found that these, when placed together with the direction of their axes coinciding, allow the light to pass through. If, however, one section is revolved npon the other, less and less of the light is transmitted, until, when their axes are at right angles $\left(90^{\circ}\right)$ to each other, the light is (for the most part) extinguished. As the revolution is continned, nore and more light is obtained throngh the sections, and after a revolution of $180^{\circ}$, the axes being again parallel, the appearance is as at first. A further revolution ( $270^{\circ}$ ) brings the axes again at right angles to each other, when the light is a second time extinguished, and so on around.

The explanation of these phenomena, so far as it can be given here, is analogors to that employed for the case of polarization by re-

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 flection. Each plate so affects the ray of light that after having passed throngh it there exist vibrations in one direction only, and that parallel to the vertical axis, the other vibrations being absorbed. If now the two plates are placed in the same position, abdc, and efgh (f. 379), the light passes through both in succession. If, however, the one is turned upon the other, only that portion of the light can pass throngh which vibrates still in the direction $a c$. This portion is determined by the resolution of the existing vibrations in accordance with the principle of the parallelogram of forces. Consequently, when the sections stand at right angles to each other (f. 380) the amount of
 transmitted light is nothing (not strictly true), that is, the light is extinguished.

The tourmaline plates, which have been deseribed, are mounted in pieces of cork and held in a kind of wire pincers (f. 381). The object to be examined is placed between them and supported there by the spring in the wire. In use they are held close to the eye, and in this position the object is viewed in converging polarized light.

Polarization by means of Nicol prisms. - The most convenient method of obtaining polarized light is by means of a Nicol prism of calcite. A
cleavage rhombohedron of calcite (the variety Iceland spar is universally used in consequence of its transparency) is obtained, having four large and two small rhombohedral faces opposite each other. In place of the latter

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planes two new surfaces are cut, making angles of $68^{\circ}$ (instead of $71^{\circ}$ ) with the obtuse vertical edges; these then form the terminal faces of the prism. In addition to this, the prism is cut through in the direction $H H$ (f. 382), the parts then polished and cenented together again with Canada balsam. A ray of light, $a b$, entering the prism is divided into two rays polarized at right angles to each other. One of these, $b c$, on meeting the layer of balsam (whose refractive index is greutir than that of calcite) suffers total reflection (p. 128), and is deflected against the blackened sides of the prism and extinguished. The other passes through and emerges at $e$, a completely polarized ray of light, that is, a ray with vibrations in one direction only, and that the direction of the shorter diagonal of the prisin (f. 383).

It is evident that two Nicol prisms can be used together in the same way as the two tourmaline plates, or the two mirrors; one is called the polarizer, and the other the analyzer. The plane of polarization of the Nicol prisms has the direction $P P($ f. 383) at right angles to which the vibrations of the light take place. A ray of light passing through one Nicol will be extinguished by a second when its plane of polarization is at right angles to that of the first prism; in this case the Nicols are said to be
 crossed. The Nicol prisms have the great advantage over the tourmaline plates, that the light they transmit is uncolored and more completely polarized.
Either a tourmaline plate or a Nicol prism may also be used in connection with a reflecting mirror. The light reflected by such a mirror vibrates in a plane at right angles to the plane of incidence (plane of polarization); that transmitted by the Nicol prism vibrates in the direction of the shorter diagonal (f. 383). Hence, when the plane of this diagonal is at right angles
 to the plane of polarization of the mirror, the reHected ray will pass through the prism; but when the two planes mentioned coincide, the planes of vibration are at right angles and the reflected ray is extinguished by the prism.

Polariscopes.*-The Nicol prisms, when ready for use, are mounted in an upright instrument, called a polariscope. Sometimes parallel, and sometimes converging, light is required in the investigations for which the instrument is used. Fig. 384 shows the polarization-microscope of Nörrenberg


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as altered and improved by Groth (see Literature, p. 160). The Nicol prisms are at $d$ and $r$, and are so momited as to admit of a motion of revolution independent of the other parts of the instrument. The lense $e$ causes the light from the ordinary mirror, $a$, to pass as a cone through the prism $d$, and the lenses at $h$ converge the light upon the plate to be examined placed at $i$. The other lenses (o) above act as a weak microscope, having a field of vision of $130^{\circ}$. The stage ( $l$ and $k$ ), carrying the olject, admits of a horizontal revolution. The distance between the two halves of the instrument is adjnsted by the screws $m$ and $n$.

When parallel light is required, a similar instrument is employed, which has, however, a different arrangement of the lenses, as shown in f .385. The objects for which these instruments, as well as the tourmaline plates, are employed, will be found described in the following pages.

The Nicol prisms are often used as an appendage to the ordinary compound microscope, and in this form are important as enabling us to examine very minute crystals in polarized light. $\dagger$

## DISTINGUISHING OPTICAL CHARACTERS OF THE CRYS. TALS OF THE DIFFERENT SYSTEMS.

It has already been remarked that all crystallized minerals group themselves into three grand classes, which are distinguished by their physical properties, as well as their geometrical form :
A. Isometric, in which the crystals are developed alike in all the several axial directions.
B. Isodiametric, including the tetragonal and hexagonal systems, whose crystals are alike in the directions of the several lateral axes, but vertically the development is unlike that laterally.
C. Anisometric, embracing the three remaining systems, where the crystals are developed in the three axial directions dissimilarly.

[^17]
## A. Isometric Crystals.

## General Optical Character.

All isometric crystals are alike in this respect that they simply refract, but do not doubly refract the light they transmit. They are optically isotrope. This follows directly from the symmetry of the crystallization. In the language of Fresnel, the elasticity of the light-ether is throughout them the same, and the light is propagated in every direction with the same velocity. There is, consequently, but one value of the index of refraction. The wave-surface is spherical. This class also includes all transparent anorphous substances, like glass.

## Optical Investigation of Isometric Crystals.

In consequence of their isotropic character, isometric crystals exhibit no speciai phenomena in polarized light. Sections of isonetric crystals may be always recognized as such by the fact that they behave as an amorphous substance in polarized light; in other words, when the Nicol prisms are crossed they appear dark, and a revolution of the section in any plane produces no change in appearance. Similarly they appear light when placed between parallel Nicols. Some anomalies are mentioned on p. 158.

Isometric crystals have but a single index of refraction, and that may be determined in the way described by means of a prism cut with its edge in any direction whatever.

Crystals of the second and third classes are optically anisotrope.

## B. Uniaxial Crystals.

## General Optical Character.

In the isodiametric crystals, those of the tetragonal and hexagonal systems, there is crystallographically one axial direction, that of the vertical axis', which is distinguished from the other lateral directions which are among themselves alike. So also the optical investigations of these crystals show that with reference to the action of light there exists a similar kind of symmetry. Light is propagated in the direction of the vertical axis with a velocity different from that with which it passes in any other direction, but for all directions at right angles to the vertical axis, or all directions making the same angle with it, the velocity of propagation is the same. In other words, the elasticity of the ether in the direction of the vertical axis is either greater or less than that in directions normal to it (analogous to the crrstallographical relation $\dot{c} \gtrless a$ ), while in the latter directions it is everywhere alike.


Optic axis.-Let a ray of light pass through the crystal in the direction of the vertical axis, $a b$, in f. 386 , its vibrations must take place in the plane at right angles to this axis; but in all directions in this plane the elasticity of the ether is the same, hence for such a ray the crystal must act as an isotiope medium; and the ray is consequently not donbly refracted and not polarized. This direction is called the opric axis.*

Double refraction.-If, on the other hand, the ray of light passes through the crystal in any other direction, it is divided into tivo rays, or donbly refracted (see f. 377), and this in consequence of the difference in the elasticity of the ether in the plane in which the ribrations take place. Of these two rays, one follows the law of ordinary refraction, and this is called the ordinary ray ; the other does not conform to this law, and is called the extraordinary ray. Both these rays are polarized, and in planes at right angles to each other; the vibrations of the extraordinary ray take place in the plane passing through the incident ray and vertical axis, called the principal section, those of the ordinary ray are in a plane at right angles to this.

Wave-surface of the ordinary ray.-The meaning of the statement that the ordinary ray follows the law of the simple refraction is this:-the index of refraction $(\omega)$ of the ordinary ray has invariably the same value, whatever be the direction in which the light passes throngh the crystal; the ammunt of deviation from the perpendicular is always in accordance with the law $\frac{\sin i}{\sin r}=n(\omega)$. In other words, the ordinary ray is propagated in all directions in the medium with the same velocity; and hence the wave-

[^18]surface is that of a sphere. Moreover, the ordinary ray always remains in the plane of incidence.

Wave-surface of the extraordinary ray.-For the extraordinary ray the law of simple refraction does not hold good. If experiments be made upon any uniaxial crystal, it will be found that the two rays are most separated when (1) the light falls perpendicular to the vertical axis. As its inclination toward the axis is diminished, the extraordinary ray approaches the ordinary ray, and coincides with it when (2) the light passes through parallel to the vertical axis. The index of refraction of the extraordinary ray varies in value, being most unlike $\omega$ for the first case supposed when the vibrations of the extraordinary ray are parallel to the axis (when it is called $\epsilon$ ), and is equal to $\omega$ for the second case supposed. The velocity of this ray is then variable in a corresponding manner. The wave-surface of the extraordinary ray is an ellipsoid of rotation. Moreover it ordiuarily does not remain in the plane of incidence.

Two cases are now possible: the index ( $\omega$ ) of the ordinary ray may be (1) greater than that of the extraordinary ray ( $\epsilon$ ), in which case the velocity of the light in the direction of the vertical axis is less than that in any other direction; or (2) $\omega$ may be less than $\epsilon$, and in this case the velocity of propagation for the light has its maximum parallel to the vertical axis. The former are called negative, the latter positive crystals. The fact alluded to here should be noted that the value of the refractive index is inversely proportional to the velocity of the light, or elasticity of the ether, in the given direction.

Negative crystals ; Wave-surface.-For calcite $\omega=1 \cdot 654, \epsilon=1.483$, it is hence one of the class of negative crystals. The former value $(\omega)$ belongs to the ray vibrating at right angles to the vertical axis, and the latter value (e) to the ray with vibrations parallel to the axis. As has been stated, the refractive index for the extraordinary ray increases from 1.483 to 1.654 , as the ray becomes more and more nearly parallel to the vertical axis. Fig. 387 illustrates graphically the relation between the two indices of refraction, and the corresponding velocities of the rays; $a b$ represents the direction of the vertical axis, that is, the optic axis. Also ma, mb represent the velocity of the light parallel to this axis, corresponding to the greater index of refraction ( $1 \cdot 654$ ). The circle described with this radius will represent the constant velocity of the ordi-
 nary ray in any direction whatever. Let further $m d, m c$ represent the velocity of the extraordinary ray passing at right angles to the axis, hence corresponding to the smaller index of refraction ( $1 \cdot 483$ ). The ellipse, whose major and minor axes are cd and $a b$, will express the law in accordance with which the velocity of the extraordinary ray varies, viz., greatest in the direction $m d$, least in the direction $a b$ in which it coincides with the ordinary ray. For any intermediate direction, hgm , the velocity will be expressed by the length of the line, $h m$.

Now let this figure be revolved about the axis $a b$; there will be generated
within an oblate ellipsoid of rotation (f. 388). The surface of the sphere is the wave-surface of the ordinary ray.
 and that of the ellipsoid of the extraordinary ray; the line of their intersection is the optic axis.

In f. 377, p. 147, the ray of light is shown divided into two by the piece of calcite; of these, $b d$, which is the more refracted, is the ordinary ray; and $b c$, which is less refracted, is the extraordinary ray.

Positive crystals; Wave-surface. - For quartz $\omega=1.548, \epsilon=1.558$. The index of refraction for the ordinary ray $(\omega)$ is less than that of the extraordinary ray ( $\epsilon$; quartz hence belongs to the class of positive crystals. The value of $\epsilon$ ( 1.558 ) for the extraordinary ray corresponds to the direction of the ray at right angles to the vertical axis, when its vibrations are parallel to this axis. $\mathrm{As}_{8}$ the direction of the ray changes and becomes more and more nearly parallel to the axis, the value of its index of re-
 fraction decreases, and when it is parallel to the latter, it has the value 1.548 . The extraordinary ray then coincides with the ordinary, and there is no double refraction; this is, as before, the line of the optic axis. The law for both rays can be represented graphically in the same way as for negative crystals. In f. $389, a m b$ is the direction of the optic axis; let $m a, m b$ represent the velocity of the ordinary ray, which corresponds to the least refractive index ( $1: 548$ ), the circle afbe will express the law for this ray, viz., the velocity the same in every direction. Moreover, let $m d, m c$ represent the velocity of the extraordinary ray, at right angles to the axis, which corresponds to the maximum refractive index $(1 \cdot 558)$; the ellipse, adbc, will express the law for velocity of the extraordinary ray, viz., least in the direction $m d$, and greatest in the direction $a b$, when it is equal to that of the ordinary ray, and varying uniformly between these limits. If the figure be revolved as before, there will be generated a sphere, whose surface is the wave-surface of the ordinary ray, and mithin it a prolate ellipsoid whose surface represents the wave-surface of the extraordinary ray.

The foilowing list includez examples of both classes of uniaxial crystals :

Negative crystals ( - ),
Calcite,
Tourmaline,
Corundum,
Beryl,
Apatite.

> Positive crystals (+),
> Quartz,
> Zircon,
> Hematite,
> Apophyllite,
> Cassiterite.

It may be remarked that in some species both + and - varieties have
been observed. Certain crystals of apophyllite are positive for one end of the spectrum and negative for the other, and consequently for some color between the two extremes it has no double refraction.


#### Abstract

These principles make the explanation of the use of tourmaline plates and calcite prism as polarizing instruments (p. 150) more intelligible.

The two rays into which the single ray is divided on passing through a uniaxial crystal are, as has been said, both polarized, the ordinary ray in a plane passing through the vertical axis and the extraordinary ray perpendicular to this. In a tourmaline plate of the proper thickness, cut parallel to the axis $\dot{c}$, the ordinary ray is absorbed (for the most part) and the extraordinary ray alone passes through, having its vibrations in the direction of the vertical axis.

In the calcite prism, of the two refracted and polarized rays, the ordinary ray is disposed of artificially in the manner mentioned (p. 151), and the extraordinary ray alone passes through, vibrating as already remarked, in the direction of the axis $\dot{c}$, or, in other words, of the shorter diagonal of the Nicol prism.

The relation of these phenomena to the molecular structure of the crystal is well shown by the effect of pressure upon a parallelopiped of glass. Glass, normally, exhibits no colored phenomena in polarized light, since the elasticity of the ether is the same in ail directions. and there is hence no double refraction. But if the block be placed under pressure, exerted on two opposite faces, the conditions are obviously changed, the density is the same in the both lateral directions but differs from that in the direction of the axis of pressure. The symmetry in molecular structure becomes that of a uniaxial crystal, and, as would be expected, on placing the block in the polariscope, a black cross with its colored rings is observed, exactly as with calcite. Similarly when glass has been suddenly and unevenly cooled its molecular structure is not homoreneous, and it will be found to polarize light, although the phenomena, for obvious reasons, will not have the regularity of the case described.

It may be added here that recent investigations by Mr. John Kerr have shown that electricity calls out birefringent phenomena in a block of glass. (Phil. Mag., l., 337.)


## Optical Investigation of Uniaxial Crystals.

Sections normal or parallel to the axis in polarized light.-Suppose a section $t$ o be cut perpendicular to the vertical axis (axial section), it has already been shown that a ray of light passing through the cerystal in this directiou suffers no change, consequently, such a section examined in parallel polarized light, in the instrument (f. 385), appears as a section of an isonetric erystal.

If the same section be placed in the other instrument (f. 384, p. 152), arranged for viewing the olject in converging light, or in the tournaline tongs, a beantiful phenomenon is observed ; a symmetrical black crosswhen the Niculs or tourmaline plates are crossed-with a series of concentric rings, dark and light, in monochromatic light, but in white light, showing the prismatic colors in succession in each ring. This is shown without the colors in f. 390, the arrangement of the colors in the elliptical rings of the colored plate (frontispiece) is similar.

This cross becomes white when the Nicols or tourmalines are in a parallel position, and each band of color in white light changes to its comple. mentary tint (f. 391). These interference figures are seen* in this form only in a plate cut perpendicular to the vertical axis, and marks the uni waich character of the crystal.

The explanation of this phenomenon can be only hinted at in this place

[^19]All the rays of light, whose vibrations coincide with the vibration-planes of either of the crossed Nicols, must necessarily be extinguished. This gives rise to the black cross in the centre, with its arms in the direction of the planes mentioned. All other rays passing through the given plate obliquely will be doubly refracted, and after passing throngh the second Nicol, thus being referred to the same plane of polarization, they will

interfere, and will give rise to a series of concentric rings, light and dark in homogeneous light, but in ordinary light showing the successive colors of the spectrum. In regard to the interference of polarized rays, the fact murt be stated that that can take place only when they vibrate in the same plane; two rays vibrating at right angles to each other cannot interfere. These interference phenomena are similar to the successive spectra obtained by diffraction gratings alluded to on p. 129. It is evident that, in order to observe the phenomena most advantageously, the plate must have a suitable thickness, which, however, varies with the refractive index of the substance The thicker the plate the smaller the rings and the more they are crowded together; when the thickness is considerable, only the black brushes are seen.

Section parallel (or sharply inclined) to the axis.-If a section of a miaxial crystal, cat parallel or inclined to the vertical axis, be examined in. parallel polarized light, it will, when its axis coincides with the direction of vibration of one of the Nicol prisms, appear dark when the prisms are crossed. If, however, it be revolved horizontally on the stage of the polariscope ( $l, l, f .384$ ) it will appear alternately dark and light at intervals of $45^{\circ}$, dark under the conditicns mentioned above, otherwise more or less light, the maximum of light being obtained when the axis of the section makes an angle of $45^{\circ}$ with the plane of the Nicol. Between parallel Nicols the phenomena are the same except that the light and darkness are reversed. When the plate is not too thick the polarized ray, after passing the upper Nicol, will interfere, and in white light, the plate will show bright colors, which change as one of the Nicols or the plate is revolved.

Examined in converging light, similar sections, when very thin, show in white light a series of parallel colored bands.

Determinution of the indices of refraction $\omega$ and $\epsilon$.-One prism will
suffice for the determination of both indices of refraction, and its edge may be either parallel or perpendicular to the vertical axis.
(a) If parallel to the vertical axis, the angle of minimum deviation for each ray in succession must be measured. The extraordinary ray vibrates parallel to, and the ordinary ray at right angles to, the direction of the edge of the prism. For convenience it is better to isolate each of the rays in succession, which is done with a single Nicol prism. If this is held before the observing telescope with its shorter diagonal parallel to the refracting edge of the prism, the ordinary ray will be extinguished and the image of the slit observed will be that due to the extraordinary ray. If held with its plane of vibration at right angles to the prismatic edge, the extraordinary ray will be extinguished and the other alone observed. From the single observed angle, for the given color, the index of refraction can be calculated, $\omega$ or $\epsilon$, by the formula given on p. 128, the angle of the prism being known.
(b) If the refracting edge of the prism is perpendicular to the vertical axis of the crystal, the same procedure is necessary, only in this case the ordinary ray will vibrate parallel to the prismatic edge, and the extraordinary ray at right angles to it. The two rays are distinguished, as before, by a Nicol prism.

Determination of the positive or negative character of the double refrac tion.-The most obvious way of determining the character of the double refraction $(\omega>\epsilon$ or $\omega \neq \epsilon)$ is to measure the indices of refraction in accordance with the principles explained in the preceding paragraphs. It is not always possible, however, to obtain a prism suitable for this purpose, and in any case it is convenient to have a more simple method of accomplishing the result.

To do this, use may be made of a very simple principle:- the + or character of a given crystal is determined by observing the effect produced when an axial section from it is combined in the polariscope with that of a crystal of knowil character.

For instance, calcite is negative, and if it be placed in conjunction with the section of a positive crystal, the whole effect observed is the same as that which would be produced if the original plate were diminished in thickness, while, if combined with a negative crystal, it is as if the plate were made thicker. It has already been remarked that, as the axial plate of a crystal increases in thickness, the number of rings visible in the field of the polariscope increases, and they become more crowded together; but, if the section is made thinner, the successive rings widen out and become less numerons. One or the other of these effects is produced by the use of the intervening section.

In the case of uniaxial crystals, however, the method which is practically most simple is that suggested by Dove-the use of an axial plate of mica of a certain thickness. The section required is a cleavage piece of such a thickness that the two rays in passing throngh suffer a difference of phase which is equal to a quarter wave-length, or an odd multiple of this.

Suppose that the section of the crystal to be examined, cut perpendicular to the axis, is brought between the crossed Nicols in the polariscope; the black cross and the concentric colored rings are of course visible. Let now, while the given section occupies this position, the mica plate be placed upon $i_{i}$, with the plane of its optic axes (determined beforchand, and the direction
marked by a line for convenience) making an angle of $45^{\circ}$ with the vibra. tion-planes of the Nicols; the black cross disappears and there remain only two diagonally situated dark spots in the place of it. Moreover, the colored curves in the two quadrants with these spots are pushed farther away from the centre than the others. The effect produced is represented in f. 392 and f. 393. If the line joining these two dark spots stands at right angles

to the axial plane of the mica, the crystal is positive (f. 392), if this line coincides with the axial plane, the crystal is negative (f. 393). The explanation of this eff.... is not so simple as to allow of being introduced here; the effect of the 1 uca is to produce circular polarization of the light which it transmits.

> With both uniaxial and biaxial crystals the student will find it of great assistance always to have at his side a good section of a positive and a negative crystal. By comparing the phenomena observed in the section under examination with those shown by crystals of known character, he will often be saved much perplexity.

For the investigation of the absorption phenomena of uniaxial crystals see p. 165 .

## Circular Polarization.

In what has been said of polarized light, in the preceding pages, it has been assumed that a polarized ray was one whose vibrations took place in a single plane, so that the plane of polarization at right angles to this was a fixed plane. Such a ray is said to be linearly polarized. There are some uniaxial crystals, however, which have the power to rotate the plane of polarization; the ray is said to be circularly polarized. They manifest this in the phenomena observed when an axial section is examned in the polariscope.

An axial section of a uniaxial crystal normally exhibits, in converging polarized light, a black cross with a series of concentric colored circles, f. 390 , p. 140 . If, however, a section of quartz be cut perpendicular to the axis and viewed between the crossed Nicols, the phenomena observed are different from these:-the central portion of the black cross has disappeared, and instead, the space within the inner ring is brilliantly colored. Furthermore, when the analyzing Nicol is revolved, this color changes from blue to yellow to red, and it is found that in some cases this
change is produced by revolving the Nicol to the right, and in other cases to the left. To distinguish between these the first are called right-handed ritating crystals, and the others left-handed. The relations here involved will be better understood if the quartz section is viewed in parallel mono. chromatic light. Under these circumstances a similar plate of calcite appears dark when the Nicols are crossed, but with quartz the maximum darkness is only obtained when the analyzer has been revolved beyond its first position a certain angle; this angle increasing with the thickness of the section, and also varying with the color of the light employed. ${ }^{\circ}$

For a section 1 mm . thick in red light, a rotation of the analyzer of $19^{\circ}$ is required to produce the maximum darkness. For yellow light the rotation is $24^{\circ}$ with a plate of the same thickness; with blue, $32^{\circ}$, and so on. The rotation of the analyzer with some crystals is to the right, with others to the left.

The explanation of these facts lies in the fact stated above, that the quartz rotates the plane of vibration of the polarized light, and the angle of rotation is different for rays of different wave-lengths. Furthernore, this rotation of the plane of vibration results from the fact that in quartz, even in the direction of its axis, donble refraction takes place. The oscillations of the particles of ether take place not in straight lines but in circles, and they move in opposite directions for the two rays, ordinary and extraordinary, and recontine to give thare pol. light on emerging form the eryesel. (A
An axial section of a quartz crystal can never appear dark between crossed Nicols in ordinary light, since there is no point at which all the colors are extinguished; on the contrary, it appears highly colored. The color depends upon the thickness of the section, and is the same as that observed in the centres of the rings in converging polarized light. If sections of a right-handed and left-handed crystal are placed together in the polariscope, the centre of the interference figure is occupied with a fourrayed spiral curve, called from the discoverer Airy's spiral. Twins of quartz crystals are not uncommon, consisting of the combination of rightand left-handed individual, which sometimes show the spirals of Airy.

It is a remarkable fact, discovered by Herschel, that the right- or lefthanded optical character of quartz is often indicated by the position of the trapezohedral planes on the crystals. When a given trapezohedral plane appears as a modification of the prism, to the right above and left bolow, the crystal is optically right-handed; if to the left above and right below, the crystal is left-handed. In f. 394 the plane is, as last remarked, left above and right below, and the crystal is hence left-handed. Cinuabar has been shown by Des Cloizeanx to possess the same property as quartz; and this is true also of some artificial salts, also solutions of sugar, etc.

In twins of quartz, the component parts may be both right-handed or both left-handed (as in those of Danphiny and the Swiss Alps); or one nay be of one kind and the other of the other. Moreover, successive layers of deposition (made as the crystal went on enlarging, and often exceedingly thin) are sometimes alternately right- and left-handed, showing a constant uscillation of polarity in the course of its formation; and, when this is the case, and the layers are regular, cross-sections, examined by polarized light, exhibit a division, more or less perfect, into sectors of $120^{\circ}$, parallel to the plane $\&$, or intc sectors of $6 v^{\circ}$. If the layers are of unequal thickness
there are broad areas of colors without sectors. Ir f. 395 (by I)es Cloizeaux, from a crystal from the Dept. of the Aude), half of each sector of $60^{\circ}$ is

right-handed, and the other half left (as shown by the arrows), and the dark radii are neutral bands produced by the overlapping of layers of the twe kinds. These overlapping portions often exhibit the phenomenon of Airy's spiral.

## C. Biaxtal Crystals.

## General Optical Character.

As in the crystalline systems, thus far considered, so also in the anisome. tric systems, the orthorhombic, monoclinic, and triclinic, there is a strict correspondence between the molecular structure, as exhibited in the geometrical form of the crystals, and their optical properties. In the crystals of these systems there is no longer one axis around about which the elasticity of the light-ether, that is, the velocity of the light, is everywhere alike. On the contrary, the relations are much less simple, and less easy to comprehend. There are two directions in which the light passes through the crystal withont double refraction-these are called the optic axes, and hence the crystals are biaxial-but in every other direction a ray of light is separated
 into two rays, polarized at right angles to each other. Neither of these conforms to the law of simple refraction. The subject was first developed theoretically by Fresuel, and his conclusions have since been fully verified by experiment.

Axes of elasticity.-In regard to the elasticity of the ether in a biaxial crystal there are (1) a maximum value, (2) a minimum value, and (3) a mean value, and these values in the crystal are found in directions at right angles to each other. In f. $396, C C^{\prime}$ represents the axis ( $\mathbf{c}$ ) of least elasticity, $A A^{\prime}$ of greatest elasticity ( $\mathfrak{a}$ ), and $B B^{\prime}$ of mean elasticity (b). A ray passing in the direc.
tion $C C^{\prime}$ vibrates in a plane at right angles, that is, parallel to $B B^{\prime}$ and $A A^{\prime}$. Similarly for the ray $B B^{\prime}$ the vibrations are parallel to $A A^{\prime}$ and $C C^{\prime}$, and for the ray $A A^{\prime \prime}$ parallel to $B B^{\prime}$ and $C^{\prime} C^{\prime}$. Between these extreme values of the axes of elasticity, the elasticity varies according to a regular law, as will be seen in the following discussion. The form of the wave-surface for a biaxial crystal may be determined by fixing its form for the planes of the axes $\mathfrak{a}, \mathfrak{b}$, and $\mathfrak{c}$.

Wave-surface.-First consider the case of rays in the plane of the axis $B B^{\prime}$ and $C C^{\prime}$ (f. 397). A ray passing in the direction $B B^{\prime}$ is separated into two sets of vibrations, one parallel to $A A^{\prime}$, corresponding to the greatest elasticity, moving more rapidly than the other set, parallel to $C C^{\prime}$, which correspond to the least elasticity. The velocities of the two sets of vibrations are made proportional to the lengths of the lines $m n$, and mo respectively, in f. 397. Again, for a ray in the same plane, parallel to $C C^{\prime \prime}$, the vibrations are (1) parallel to $A A^{\prime}$, and propagated faster (greatest elasticity) than the other set; (2) parallel to $B B^{\prime}$ (mean elasticity). Again, in f. 397, on the line $C^{\prime} C^{\prime \prime}, m n^{\prime \prime}$, and $m q^{\prime \prime}$ are made proportional to these two velocities;
 here $m n=m n^{\prime \prime}$, and for a ray in the same plane in any other direction, there will be one set of vibrations parallel to $A A^{\prime}$, with the same velocity as before, and another set at right angles with a velocity between mo and $m q^{\prime \prime}$, determined by the ellipse whose semi-axes are proportional to the mean and least axes of elasticity.

Fig. 397 then represents the section of the wave-surface through the axes $C C^{\prime \prime}$ and $B B^{\prime}$. The circle $n n^{\prime \prime}$ shows the constant velocity for all vibrations parallel to $A A^{\prime}$, and the ellipse the variable values of the velocity for the other set of vibrations at right angles to the first.

Again, for a ray in the plane $A A^{\prime}$, $B B^{\prime}$, the method of the construction is similar. The vibrations will in every case take place in the plane at right angles to the direction of the ray, which plane must always pass through the axis $C^{\prime} C^{\prime}$ of least elasticity. Hence for every direction of the ray in the plane mentioned, one set of vibrations will always
 be parallel to $C C^{\prime}$, and hence be propagated with a constant velucity
$=m o^{\prime}, \mathrm{f} .398$ ), and hence this is expressed by the circle $o o^{\prime}$. The other set of vibrations will be at right angles to $C C^{\prime}$, and the velocity with which they are propagated will vary according as they are parallel to $A A^{\prime}$ (=mn, f. 398), or parallel to $B B^{\prime}\left(=m q^{\circ}\right)$, or some intermediate value for an intermediate position.

The section of the wave-surface is consequently a circle within an ellipse.
Finally, let the ray pass in some direction in the plane $C^{\prime} C^{\prime}, A A^{\prime}$, of least and greatest elasticity, the section of the wave-surface is also a circle and ellipse.

Suppose the ray passes in the direction
 parallel to $A A^{\prime}$, the vibrations will be (1) parallel to $C C^{\prime \prime}$, and (2) parallel to $B B^{\prime}$, those (1) parallel to $C C^{\prime}$ (least axis of elasticity) are propagated more slowly than those (2) parallel to $B B^{\prime}$ (axis of mean elasticity). In f. 399, on the line $A A^{\prime}$, lay off $m v^{\prime}$ and $m q^{\prime}$ proportional to these two values.

Again, for a ray parallel to $C C^{\prime}$ the vibrations will take place (1) parallel to $A A^{\prime}$, and (2) parallel to $B B^{\prime}$, the former will be propagated with greater velocity than those latter. These two values of the velocity in the direction $C^{\prime} C^{\prime}$ are represented by $m n^{\prime \prime}$ and $m q^{\prime \prime}\left(=m q^{\prime}\right)$. For any intermediate position of the ray in the same plane there will always be one set of vibrations parallel to $B B^{\prime}$ ( $m q^{\prime}=m q^{\prime \prime}, \mathrm{f} .399$, hence the circle). The other set at right angles to these will be propagated with a velocity va-
 rying according to the direction, from that corresponding to the least axis of elasticity (represented by $m o^{\prime}$, f.399), to that of the greatest axis of elasticity ( $m n^{\prime \prime}$ ).

Optic axes.-It is seen that the circle, representing the uniform velocity of vibrations parallel to $b$, and the ellipse representing the varying value of the velocity for the vibrations at right angles to these, intersect one inother at $P, P^{\prime}$, f. 399. The obvious meaning of this fact is that, for the directions $m P$, and $m P^{\prime}$, making equal angles with the axis $C C^{\prime}$, the velucity is the same for both sets of vibrations; these are not separated from each other, the ray is not doubly refracted, and not polarized.
These two directions are called the optic axes. All anisometric crrstals have, as has been stated, two optic axes, and are hence called biaxial.

The complete wave-surface of a biaxial crystal is constructed from the three sections given in $\mathrm{f} .397,398,399$. It is shown graphically in f .400 , where the lines $P P$, and $P^{\prime} P^{\prime}$ are the two optic axes.

Bisectrices, or Mean-lines.-As shown in f. 399, the optic axes always lie in the plane of greatest $(\mathfrak{a})$ and least $(\mathfrak{r})$ elasticity, and the value of the optic axial angle is known when the axes of elasticity are given as stated below. The axis of elasticity which, as the line $C C^{\prime}, f .399$, bisects the acute angle is called the acute bisectrix, or first mean-line (erste Mittellinie, Germ.), and that bisecting the obtuse angle, the obtuse bisectrix, or second mean-line (zweite Mittellinie, Germ.).

Positive and negative crystals.-When the acute bisectrix is the axis of least elasticity ( $\mathfrak{c}$ ), it is said to be positive, and when it is the axis of greatest (a) elasticity, it is said to be negative. Barite is positive, mica negative.

Indices of refraction.-It has been seen that in uniaxial crystals there are two extreme values for the velocity with which light is propagated, and corresponding to them, and inversely proportional to them, two indices of refraction. Similarly for biaxial crystals, where there are three axes of elasticity, there are three indices of refraction-a maximum index $a$, a minimum $\gamma$, and a mean value $\beta ; a$ is the index for the rays propagated at right angles to $\mathfrak{a}$, but vibrating parallel to $\mathfrak{a} ; \beta$ is the index for rays propagated perpendicularly to $b$, by vibrations parallel to $b ; \gamma$ is the index for rays propagated perpendicularly to $\mathfrak{c}$, but vibrating parallel to $\mathrm{c} . \quad a=\frac{1}{\mathfrak{a}}, \beta=\frac{1}{\mathfrak{b}}, \gamma=\frac{1}{\mathfrak{c}}$.

If $\boldsymbol{a}, \beta$, and $\gamma$ are known, the value of the optic axial angle (2 $V$ ) can be calculated from them by the following formula:

$$
\cos V=\sqrt{\frac{\frac{1}{\beta^{2}}-\frac{1}{\gamma^{2}}}{\frac{1}{a^{2}}-\frac{1}{\gamma^{2}}}}
$$

Dispersion of the optic axes.-It is obvicus that the three indices of refraction may have different values for the different colors, and as the angle of the optic axes, as explained in the last paragraph, is determined by these three values, the axial angle will also vary in a corresponding manner.

This variation in the value of the axial angle for rays of different wave lengths is called the dispersion of the axes, and the two possible cases are distinguished by writing $\rho>v$ when the angle for the red rays $(\rho)$ is greater than for the blue (violet, $v$ ), and $\rho<v$ when the reverse is true.

In the properties thus far mentioned, the three systems are alike; in details, however, they differ widely.

## Practical Investigation of Biaxial Crystals.

Interference figures.-A section cut perpendicular to either axis will show, in converging polarized light, a system of concentric rays analogons to thnee of uniaxial crystals, f. 390 , but more or less clliptical. There is, moreover, no black cross, but a single black line, which changes its position as the Nicols are revolved.

If a section of a biaxial crystal, cut perpendicularly to the first, that is acute, bisectrix, is viewed in the polariscope, a different phenomenon is observed.

There are seen in this case, supposing the plane of the axes to make an angle of $45^{\circ}$ with the planes of polarization of the crossed Nicols, two black hyperLnlas, marking the position of the axes, a series of elliptical curves surrounding the two centres and finally uniting, forming a series of lemniscates. If monochromatic light is employed, the rings are alternately light and dark; if white light, each ring shows the successive colors of the spectrum. If one of the Nicol prisms be revolved, the dark hyperbolic brushes gradually become white, and the colors of the rings take the complementary tints after a revolution of $90^{\circ}$. Since the black hyperbolic brushes mark the position of the optic axes, the smaller the axial angle the nearer together are the hyperbolas, and when the angle is very small, the axial figure

observed closely resembles the simple cross of a uniaxial crystal. On the other hand, when the axial angle is large the hyperbolas are far apart, and mav even be so far apart as to be invisible in the field of the polariscope.

When the plane of the axes coincides with the plane of vibration for either Nicol, these being crossed, an unsymmetrical black cruss is observed, and also a series of elliptical curves. Both these figures are well exhibited 011 the frontispiece; the one gradually changes into the other as the crystal-section - is revolved in the horizontal plane, the Nicols remaining stationary.

A section of a biaxial crystal cut perpendicular to the obtuse bisectrix will exhibit the same figures under the same conditions in polarized light, when the angle is not too large. This is, however, generally the case, and in consequence the axes suffer total reflection on the inner surface of the section, and no axial figures are visible. This is sometimes the case also
with a section cut normal to the acute bisectrix, when the angle is large. A micrometer scale in the polariscope, f. 384, allows of an approximate measurement of the axial angle; the value of each division of the scale being known.

Measurement of the axial angle.*-The determination of the angle made by the optic axes is of the highest importance, and the method of procedure ofiers no great difficulties. Fig. 401 shows the instrunent recommended for this purpose by DesCloizeaux ; its general features will be understood without detailed description; some improvements have been introduced by Groth, which make the instrument more accurate and conrenient of use. The section of the crystal, cut at right angles to the bisectrix, is held in the pincers at $c$, with the plane of the axes horizontal, making an angle of $45^{\circ}$ with the plane of vibration of the Nicols ( $N N$ ). There is a cross-wire in the focus of the eye-piece, and as the pincers holding the section are turned by the screw $F$, one of the axes, that is one black hyperbola, is brought in coincidence with the vertical cross-wire, and then, by a further revolution of $F$, the second. The angle which the section has been turned from one axis to the second, as read off at the vernier $H$ on the graduated circle above, is the apparent angle for the axes of the given crystal as seen in the air (aca, f. 402). It is only the apparent angle, for, owing to the refraction suffered on passing from the section of the crystal to the air, the true axial angle is more or less increased, according to the refractive index of the given crystal.

This being understood, the fact already
 stated is readily intelligible, that when the axial angle exceeds a certain limit, the axes will suffer total reflection (p. 128), and they will be no longer visible at all. When this is the case, oilt or some other medinm with high refractive power is made use of, into which the axes pass when no longer visible in the air. In the instrument described a small receptacle holding the oil is brought between the tubes, as seen in the figme, and the pincers holding the section are immersed in this, and the angle measured as before.

In the majority of cases it is only the acute axial angle that it is practicable to measure; but sometimes, especially when oil is made use of, the obtuse angle can also be determined from a second section normal to the ubtuse bisectrix.

If $E=$ the apparent semi-axial angle in air (f. 402).
$\int H_{a}=$ the apparent semi-acute angle in oil.
$\left\{H_{o}=\right.$ " " " obtuse " " "
$V_{a}=$ the real (or interior) semi-acute angle (f. 402).
$V_{o}=$ semi-obtuse (f. 402).
$n=$ index of refraction for the oil.
$\beta=$ the mean refractive index for the given crystallized substance.

[^20]$$
\sin E=\dot{n} \sin H_{a} ; \sin V_{\alpha}=\frac{n}{\beta} \sin H_{a} ; \sin \nabla_{o}=\frac{n}{\beta} \sin H_{o} .
$$

These formulas give the true interior angle from the measured apl arent angle when the mean refractive index $(\beta)$ is known.

If, however, it is possible to measure both the acute and obtuse apparent angles, the true angle, and also the value of $\beta$, can be determined from them. For $\sin V_{o}=$ cos $V_{a}$, hence :

$$
\tan V_{a}=\frac{\sin H_{a}}{\sin H_{o}} ; \beta=n \frac{\sin H_{a}}{\sin V_{a}}=n \frac{\sin H_{o}}{\cos \bar{V}_{a}}=\frac{\sin E}{\sin V_{a}} .
$$

In measuring this angle, if white light is employed, the colors being separated, the position of the hyperbolas is a little uncertain; hence it is always important to measure the angle for monochromatic light, red and yellow and blue particularly. This is especially essential where the dispersion of the axes is considerable.

Determination of the indices of refraction.*-The values of the three indices of refraction, $a, \beta, \gamma$, for biaxial crystals, may be determined from three prisms cut with their refracting edges parallel respectively to the three axes of elasticity $\mathfrak{a}, \boldsymbol{b}$, and $\mathfrak{c}$. In cach case, after the angle of the prism has been measured, the angle of minimum deviation must be measured for that one of the two refracted rays whose vibrations are parallel to the edge of the prism ; the formula of p. 128 is then employed.

It is possible, however, to obtain the values of $a, \beta$, and $\gamma$ with two prisms; in this case one of the prisms must be so made that its vertical edge is parallel to one axis of elasticity, while the line bisecting its refracting angle at this edge is parallel to a second. In the case of such a prism the minimum deviation of the ray is obtained for both rays, that lhaving its vibrations parallel to the prism-edge, and that vibrating at right angles to this, that is parallel to the bisector of the prismatic angle.

Of the three indices of refraction, $\beta$ is one which it is most important to determine, since by means of it, in accordance with the above formulas, the true value of the axial angle can be calculated from its apparent value in air. The prism to give the value of $\beta$ should obviously have its refracting edge parallel to the mean axis of elasticity $b$, that is at right angles to the plane of the optic axes.

Determination of the positive or negative character of biaxial crystals. -The question of the positive or negative character of a biaxial crystal is determined from the values of the indices of refraction, where these can be obtained. If f , the axis of least elasticity, is the acute bisectrix, the crystal is optically positive ; if $\mathfrak{a}$, the axis of greatest elasticity, is the acute bisectrix, the crystal is optically negative; in the former case the value of $b$ is nearer that of $\mathfrak{c}$ than of $\mathfrak{a}$, in the second case the reverse of this is true.

There is, however, a more simple method of solving the problem, as was remarked also in regard to uniaxial crystals. The methods are similar.

The quarter-undnlation mica plate may be employed just as with uniaxial crystals, but its use is not very satisfactory excepting when the axial divergence is quite small. In this case it can be employed to advantage: the
plane of the axes of the crystal investigated being made to coincide with the ribration-plane of one of the Nicols. The more general method is the employment of a wedge-shaped piece of quartz; this is so cut that one surface coincides with the direction of the vertical axis, and the other makes an angle of $4^{\circ}$ to $6^{\circ}$ with it. By this means a section of varying thickness is obtained. The section to be examined normal to the acute bisectrix is brought between the crossed Nicols of the polariscope (f. 384), and with its axial plane making an angle of $45^{\circ}$ with the polarization-plane of the Nicol prisms; that is, so that the:black hyperbolas are visible. The quartz wedge is now introduced slowly between the section examined and the analyzer; in the instrument figured a slit above gives an opportunity to insert it. The quartz section is introduced first, in a direction at right angles to the axial plane, that is, to the line joining the hyperbolas, of the plate investigated ; and second, parallel to the axial plane, that is, in the direction of the line joining the hyperbolas. In one direction or the other it will be seen, when the proper thickness of the quartz wedge is reached, that the central rings appear to increase in diameter, at the same time advancing from the centre to the extremities.

The effect, in other words, is that which would have been produced by the thinning of the given section. If the phenomenon is observed in the first case when the axis of the quartz is parallel to the axial plane, that is to the obtuse bisectrix, it shows that this bisectrix must have an opposite sign to the quartz, that is, the obtuse bisectrix is negative, and the acute bisectrix positive. If the mentioned change in the interference figures takes place when the axis of the quartz is at right angles to the axial plane, then obvionsly the opposite must be true and the aente bisectrix is negative.

The same effect may be obtained by bringing an ordinary quartz section of greater or less thickness, cut normal to the axis, between the analyzer and the crystal examined, and then inclining it, first in the direction of the axial plane, and again at right angles to it. The method of investigation with the quartz wedge can be applied even in those cases where the axial angle is too large to appear in the air.

For the investigation of the absorption phenomena of biaxial crystals, see p. 165.

## Distinguishling Optical Characters of Orthorhombic Crystals.

In the Orthorhombic System, in accordance with the symmetry of the crystallization, the three axes of elasticity coincide with the three crystallographic axes. Further than this, there is no immediate relation between the two sets of axes in respect to magnitude, for the reason that, as has been stated, the choice of the crystallographic axes is arbitrary, and has been made, in most cases, without reference to the optical character.

Schranf has proposed that the crystallographic vertical axis (c) should be always made to coincide with the acute bisectrix, which would be very desirable, espiecially, as urged by him, in showing the true relations between the orthorhombic and hexagonal systems. Of course, this suggestion can be carried out only in those species in which the optical character is known.

Schrauf (Phys. Min., p. 302, 303) has shown there is a close analogy between certain


#### Abstract

orthorhombic crystals whose prismatic angle is near $120^{\circ}$ (compare remarks on twins, p. 96) and the crystals of the hexagonal system. With these the acute bisectrix is uniformly parnllel to the prismatic edge, and normal to the six-sided basal plane, analogous to the one optic axis of true hexagonal forms. Moreover, he shows that the nearer the prismatic angle approaches $120^{\circ}$, the less the difference between the three axes of elasticity, and the nearer the approach to the uniaxial character. By the combination of thin plates of a biaxial mica optical phenomena may, under some conditions, be observed in polarized light which are similar to those shown by uniaxial crystals. Similarly twins of chrysoberyl (p. 97) have been described which in spots gave the axial image of uniaxial crystals. This subject has been investigated by Reusch (Pogg. exxxvi., 626, 637, 1869), and later by Cooke (Am. Acad. Sci., Boston, p, 35, 1874).


## Practical Optical Investigation of Orthorhombic Crystals.

Determination of the plane of the optic axes.-The position of the three axes of elasticity in an orthorhombic crystal is always known, since they must coincide with the crystallographic axes ; but the plane of the optic axes, that is, of the axes of greatest (a) and least ( $\mathfrak{c}$ ) elasticity, must in each case be determined. This plane will be parallel to one of the three diametral or pinacoid planes. In order to determine in which the axes lie, it is necessary to cut sections parallel to these three directions; one of these three sections will in all ordinary cases show, in converging polarized light, the interference figures peculiar to biaxial crystals. It is evident, too, that two of the three sections named determine the character of the third, so that the plane of the optic axes and the position of the acute bisectrix can be in practice generally told from them.

Measurement of the axial angle, $\rho \lesseqgtr v$.-From the section showing the axial figures, that is, normal to the acute bisectrix, the axial angle can be measured in the manner which has been described (p. 149). If it is practicable to determine also the obtuse axial angle, from a second section normal to the obtnse bisectrix, it will be possible to calculate the trtue axial angle from these data, and also the mean index of refraction ( $\beta$ ).

There is further to be determined the dispersion of the axes. Whether the axial angle for red rays is greater or
 less than for blue ( $\rho>v$, or $\rho<v$ ) can be seen immediately from the figure of the axes, as in $\mathrm{f} .1 a, 1 b$, in the colored plate, (frontispiece). It is obviously true in this case, from f. $1 a$, as also f. $1 b$, that the angle for the blue rays is greater than that for the red $(\rho<v)$, and so in gencral. This same point is also accurately determined, of course, by the measured angle for the two monochromatic colors.
In all cases the same line will be the bisectrix of the axial angle for both blue and red rays, so that the position of the respective axes is symmetrical with reference to the bisectrix. In f. 403 , the dispersion of the axes is illustrated, where $\rho<v$; it is shown also that the lines, $B^{1} B^{1}$ and $B^{2} B^{2}$, bisect the angles of both red ( $\rho O \rho^{\prime}$ ) and blue $\left(v O v^{\prime}\right)$ rays. It also needs no further explanation that for a certain relation
of the refractive indices of the different colors, the acute bisectrix of the axial angle for red rays may be the obtuse bisectrix for the angle for blue rays.

Indices of refraction, etc.-The determination of the indices of refraction and the character ( + or - ) of the acute bisectrix is made for orthorhombic crystals in the same way as for all biaxial crystals (p. 150). It is merely to be mentioned that, since the axes of elasticity always coincide with the crystallographic axes, it will happen not infrequently that crystals without artificial preparation will furnish, in their prismatic or dome series, prisms whose edges are parallel to the axes of elasticity, and consequently at once suitable for the determination of the indices of refraction.

## Distinguishing Optical Ciaracters of Monoclinic Crystals.

Position of the axes of elasticity.-In crystals belonging to the monoclinic system one of the axes of elasticity always coincides with the orthodiagonal axis $b$, and the other two lie in the plane of symmetry at right angles to this axis. Here obviously three cases are possible, according to which two of the axes, $\mathfrak{a}, \boldsymbol{b}$, or $\mathfrak{c}$, lie in the plane of symmetry.

Corresponding to these three positions of the axes of elasticity, there may occur three kinds of dispersion of these axes, or dispersion of the bisectrices. This dispersion arises from the fact that, while the position of one axis of elasticity is always fixed, the position of the other two is indeterminate and for the same crystal may be different for the different colors, so that the Disectrices of the different colors may not coincide.

Dispersion of the bisectrices.-1. The bisectrices, that is, the axes of greatest and least elasticity, lie in the plane of symmetry, while the orthodiagonal axis $b$ coincides with $\mathbf{b}$. The optic axes here suffer a dispersion in this plane of symmetry, and, as already stated, they do not lie symmetrically with reference to the acute bisectrix. This is illustrated in f. 404 , where $M M$ is the bisectrix for the angle, $v O v^{\prime}$, and $B B$ for the angle $\rho O \rho^{\prime}$. This kind of dispersion is called by DesCloizeaux inclined (dispersion inclinée).
2. The second case is that where the plane of the optic axes is perpendicular to the plane of symmetry, and the acute bisectrix stands at right angles to the orthodiagonal axis $b$. In other words, the acute bisectrix and the axis of mean elasticity both lie in the plane of symmetry. In this case also dispersion
 of the axes may take place, and in this way-the plane of the optic axes for all the colors. lies parallel to the orthodiagonal, but these planes may have different inclinations to the ve tical axis. This is called horizontal dispersion by DesCloizeaux.
3. Still again, in the third place, the plane of the optic axes lies perpen dicular to the plane of symmetry; but in this case the acute bisectrix is parallel to the crystallographic axis $b$, so that the obtuse bisectrix and axis of mean elasticity lie in the plane of symmetry. The dispersion which
results in this case is called by DesCloizeaux crossed (dispersion tournante or croisée).

Dispersion as shown in the interference figures.-If an axial section of a monoclinic crystal be examined in converging polarized light, the kind of dispersion which characterizes it will be indicated by the nature of the interference figures observed; the three cases are illustrated by the figures upon the frontispiece, taken from DesCloizeaux. (frontispiece).

Figs. $1 a, 1 b$ represent the interference figures for an orthorhombic crystal (nitre), characterized by the symmetry in the size of the rings, and the distribution of the colors. Figs. $2 a, 2 b$ (diopside), $3 a, 3 b$ (orthoclase), $4 a, 4 b$ (borax), are examples of the corresponding figures for monoclinic crystals, characterized as such more or less distinctly by the want of symmetry in the size of the rings about the two axes, and the irregularity in the arrangement of the colors.
(1) Inclined dispersion.-Where the axes are not symmetrically situated with reference to the acute bisectrix. The relation of the two axial figures is illustrated by f. 405. In f. $2 a, 2 b$ this kind of dispersion is indicated by


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the position of the red and blue at the centres of the rings, and on the borders of the hyperbolas, compare $\mathrm{f} .1 a, 1 b$ of the normal figure, where there is no dispersion of the bisectrices.
(2) Horizontal dispersion, where the planes of the optic axes for the different colors make different angles with the axis.-This is illustrated by f. 406. The effect upon the interference figures is seen in $f .3 a, 3 b$ of the plate, by comparing the colors within the rings ( $\mathrm{f} .3 a$ ), and on the borders of the hyperbolas (f. 3b), with f. $1 a, 1 b$.
(3) Crossed dispersion, where the acute bisectrix coincides with the crystallographic axis $b$.-This is illustrated in f. 407, and the interference figures belonging to this kind of dispersion are seen in f. $4 a, 4 b$ of the plate, compared as before with $1 a, 1 b$, and with the other figures.

## Practical Optical Investigation of Monoclinic Crystals.

Determination of the position of the axes of elasticity, that is, the directions of vibration. Stauroscope. -The position of one axis of elasticity is alone known, since, as has been stated, it coincides with the crystallographic axis $b$. In order to determine the position of the other axes in the plane of symmetry, where they necessarily lie, use is made of an instrument, first proposed by von Kobell, called the Stauroscope. The principle of this instrunent is very simple. Suppose that the two Nicols in the polariscope ( $f .385$ ) have their planes of polarization crossed, causing the maximum extinction of light. Now, if a section of any biaxial crystal is brought
between them, obviously, if the position of its two rectangular axes of elasticity, which are its two directions of vibration, coincide with those of the two Nicols, it will produce no change in appearance; the field of the polariscope, which was dark before, remains dark. But suppose, on the other hand, that it is placed in any other position ins the plane, so that its two rectangular directions of vibration do not coincide with those of the Nicols, the field is no longer dark, but more or less light. The reason fol this is, that the light from the lower Nicol meeting the crystal plate is separated, according to the law of the parallelogran of forces, into two sets of vibrations, which are again resolved by the analyzing Nicol, and only one set extinguished by it. If, however, the plate be gradually changed in position, that is, revolved horizontally, until its vibration-directions (axes of elasticity) coincide with those of the Nicols, then, as at first, the light is extinguished. If the angle is measured which it is necessary to revolve the section to accomplish the result just remarked, that will be the angle between the direction of one of the axes of elasticity of the plate in its original position and the vibration-plane of the Nicol.

In figure 408, let the two larger rectangular arrows represent the vibrationdirections for the two Nicols, and between the two prisuns suppose a section of a monoclinic crystal, $a b c d$, to be placed so that one edge of a known crystallographic plane (eg., $i-i$ ) coincides with one of these lines. The field of the microscope, dark before, since the prisms were crossed, is no longer so, and becomes dark again, as explained, only when the crystal is revolved so that its vibration-directions (the smaller dotted arrows) coincide with those of the Nicols, which is indicated by the maximum extinction of the light. The crystal has then the position $a^{\prime} b^{\prime} c^{\prime} d^{\prime}$. The angle (f. 408), which it
 has been necessary to revolve the plate to obtain the effect described, is the angle which one of the axes of elasticity in the given plate makes with the given crystallographic edge $i-i$.

The preceding explanations cover everything that is essential in the Stauroscope; but a variety of improvements have been introduced, which practically make the measurements by means of the instrument much more easy and accurate.

It will be seen that the most important feature is the point where the maximum extinction of the light occurs ; this, however, is not easy for the eye to decide upon, and if the trial is made, it will be found that the change produced by a revolution of several degrees is hardly perceptible. To overcome this difficulty, von Kobell proposed to introduce a section of calcite just below the analyzer, because its interference figure gives a better opportunity to judge of a change in the intensity of the light. A still better plan is to introduce a composition plate of calcite, as proposed by Brezina, giving a peculiar interference figure, a very slight change in which destroys its symmetry, and it takes its normal form only when the planes of polariza tion of the two Nicols are exactly at right angles. Supposing this to be the case, when the crystal has been introduced the interference figure is disturbed, it. returns to its normal appearance only when the crystal has been revolved
to the point where the vibration-directions of the Nicols and crystal section exactly coincide.*

It will be observed again, that it is essential that the direction of the known edge of the crystal should be exactly parallel to the vibration-direction of one of the Nicols. This condition, in the case of small crystals especially, is hard to fulfil, and to accomplish it most satisfactorily Groth has proposed to use the plate shown in f. 409.

The plate of glass, $v$, held in its present position by the spring, has one edge polished, which adjoins $u$, and the direction
 of this is made to coincide exactly with the line joining the opposite zero points of the gradua tion. The crystal section is attached to this plate over the hole seen in $v$, and with a plane of known crystallographic position, either $O, i-\bar{\imath}$ or a plane in that zone or a corresponding edge, coinciding with the direction of the polished edge of the plate. Whether this coincidence is exact can be tested by the reflective goniometer. In order to eliminate any small error, Groth proposes to measure the divergence from the exact coincidence, and then to make a corresponding correction, for which he furnishes a series of tables.

After the adjustment of the crystal section on the plate, the latter is inserted in its place, the whole plate, $l, k$, occupying the position indicated in f. 385, and the Nicols so adjusted that the plane of vibration of one coincides with the line $0^{\circ}$ to $180^{\circ}$. The angle of revolution of the plate, $l$, is obtained from the graduated scale on $k$.

It is not always easy to make the adjustment of the Nicols alluded to, but the error arising when the vibration-plane of the Nicol does not coincide with the line $0^{\circ}$ to $180^{\circ}$ is easily eliminated. This is accomplished by removing the plate $v$, and, without disturbing the crystal section, restoring it to its place in an inverted position. The measured angle, if before too great, will now be as much too small, and the arithmetical mean of the two measurements will be the true angle.

Reference further may be made to Groth, Pogg. Ann., cxliv., 34, 1871.
Determination of the plane of the optic axes. -The investigation of a section of a monoclinic crystal parallel to the plane of symmetry determines the position of the two remaining axes of elasticity, but it does not fix the relative position of the greatest and least axes of elasticity, that is, the plane of the optic axes. To solve the latter point, sections normal to each of the three axes must be examined in converging polarized light, and one of them will show the characteristic interference figures. The section parallel to the plane of symmetry is first to be examined, and if it does not show the axes even in oil, one or both of the other sections spoken of mnst be employed.

Axial angle, dispersion, etc.- The method of measuring the axial angle has been already explained, and if this is determined for the different colors it will determine the dispersion of the axes $\rho \lesseqgtr v$.

The dispersion of the axes of elasticity has been shown to be always indicated by the character of interference figures; its amount, where con-
siderable, may be determined by making the stauroscopic measurements for different colors.

The remaining points to be investigated, the indices of refraction, and the + or - character of the crystal, need no further explanation beyond that which has been given, pp. 150, 151.

## Distinguishing Optical Characters of Triclinic Crystals.

The crystals of the triclinic system are characterized by their entire want of crystallographic symmetry, the position and inclination of the axes being entirely arbitrary, and it follows from this that there is no necessary connection between them and the rectangular axes of elasticity. More than one of the three kinds of dispersion mentioned on p .154 may occur in a single crystal, and the interference figures will indicate the existence of both.

The practical investigation of triclinic crystals optically involves great difficulty; in general a series of successive trials are required to determine the position of the axes of elasticity. When these are found, the axial sec-tions can be prepared and the axial angle determined, and the other points settled as with other biaxial crystals.

## Effect of Heat upon the Optical Cifaracters of Crystals.

In addition to the ordinary investigation of crystal-sections in the polariscope, it is often important to determine the influence of heat upon the optical character of crystals. The axial angle may be measured at any required temperature by the use of a metal air-bath. This is placed at $C \prime$, (f. 401), and extends beyond the instrument on either side, so as to allow of its being heated with gas burners; a thermometer inserted in the bath makes it possible to regulate the temperature as may be desired. This bath has two openings, closed with glass plates, corresponding to the two tubes carrying the lenses, and the crystal-section, held as usual in the pincers, is seen through these glass windows.

The conclusions of DesCloizeaux (see Literature) as to the influence of heat upon the optical characters of crystals are as follows:
(1) Uniaxial crystals appear to be uninflnenced by a heating of from $10^{\circ}$ to $190^{\circ}$ C. (2) Biaxial crystals of the orthorhombic system suffer a greater or less change in axial angle. (3) Biaxial crystals of the monoclinic system suffer a change in axial angle, and in addition also in the plane of the axes when it is not the plane of syminetry. Triclinic crystals also show a little change in the position of the axes.

A striking example of the change in axial divergence is furnished by gypsum. At ordinary temperatures the axes lie in the plane of symmetry $(i-i)$; at $80^{\circ} \mathrm{C}$. they unite in a line making an angle of $37^{\circ} 28^{\prime}$ with a normal to $O$; and with an increased temperature they again separate in a plane perpendicular to $i$ - $i$. DesCloizeaux found that the feldspars, when heated up to a certain point, suffer a change in the position of the axes, and if the heat becomes greater and is long continued, they do not return again to their original position, but remain altered. . Weiss* has made use of this principle

[^21]to determine at what temperature certain feldspathic rocks were formed This constant change of axial angle upon heating is true also of brookite, zoisite, and other minerals. The investigations of Pfaff show that the optical properties of some uniaxial crystals also are affected by heating, though to no great extent. Pogg., cxxiii., 179, cxxiv., 448, etc.

## Anomalies Exhibited by some Crystals in their Optical Phenomena.*

There are a considerable number of crystals of the three classes, which, from a variety of canses, exhibit irregularities in their optical characters; some of the more important cases are mentioned here.

Isometric crystals.-Boracite, and also senarmontite, sometimes exhibit interference figures resembling closely those of biaxial crystals. In the case of boracite this is explained by DesCloizeaux as due to the presence of enclosed crystals of parasite formed by alteration. Perofskite is also strongly doubly refracting, and in polarized light appears to be biaxial, althongh, as shown by Kokscharow, it is isometric in crystallographic relations. The irregularities are supposed by him to be cansed by the want of homngeneity in the internal structure of the crystals.

The properties of double refraction possessed by some substances, crystallized and non-crystallized, which are normally isotrope, are explained by Biot to be due to lamellar polarization. This is analogous to the production of polarized light by means of a series of thin plates (see p. 132). Alum crystals have often the lamellar structure, which canses these phenomena.

Analcite and leucite have been included in the list of isometric crystals, which exhibit anomalous optical characters; but the most accurate erystallographic determination has referred both species to the tetragonal system. Tension or compression at the time of crystallization may canse isotropic erystals to polarize light; Schrauf has described a uniaxial diamond, and it was long since shown by Brewster that some diamonds give evidence in polarized light of compression about interior cavities.

Uniaxial crystals.-A want of homogeneity in the crystals, as shown by DesCloizeanx, may cause miaxial crystals to exhibit in polarized light a variety of abnormal phenomena. In some cases the axial figures resemble those of biaxial crystals, the cross in the middle of the field (f. 390) not being closed, but separated into two hyperbolas, lying near each other. Beryl, zircon, vesuvianite, and apatite are examples. That such crystals are nevertheless uniaxial is proved by the fact that the opening of the cross is independent of the position of the Nicols, and is not altered if the section is turned in a horizontal plane. If this is not true, or if, when the section is heated ( p .157 ) the distance between the hyberbolas is altered, it is a proof that the irregularity is not due to lamellar polarization, but that the two indices of refraction are not exactly eqnal, and consequently that the erystal is not strictly uniaxial. In such cases a revision of the crystallographical elements is desirable.

The axial figure shown by a section of apophyllite is peculiar, exhibiting

[^22]a series of rings alternately dark violet, and yellow. The explanation is found in the fact previously stated, that it is positive for red rays, negative for blue, and does not doubly refract yellow light.

Among biaxial crystals irregularities in the optical phenomena are often observed. They are due in part to want of homogeneity, in part to twin structure, and also to other canses. In brookite the planes of the axes for red and blue rays are at right angles to each other, and hence the axial figures vary much from those normally observed; in titanite the axial angle for the two colors is widely different, and this also gives rise to an axial figure of abnormal appearance.

Irregular structure, due to twinning, is a frequent cause of peculiar optical phenomena; crystals, in external form apparently simple, often show themselves to be made up of irregular banded layers in twinned position, when examined in polarized light; this is true of many minerals.

In some crystals, as occasionally in the epidote from the Untersulzbachthal in the Tyrol, the biaxial figures may be observed imnediately, withont the use of the polariscope. This is due to the complex twinned structure of the crystal, a thin lamella in reverse position being enclosed in the interior, so that the parts of the cirystal on either side act as polarizer and analyzer.

## Practical Suggestions in regard to the Preparation and use of Crystal Sections maile for Optical Examination.

The most important task is the preparation of a plate for examination in the Stauroscope, or for the observation of the axial interference-figures. In this we are often assisted by the cleavage, which sometimes makes it possible to obtain the required section without the labor of cutting it. This is conspicuously the cuse with mica; also with topaz and anhydrite, and other minerals. Sometimes the natural surfaces need to be made smooth and polished. Furthermore natural crystals sometimes occur in a tabular form, thin and transparent enough to answer the purpose; this is true of the crystals of wulfenite from Utah. In most cases, however, the section must be actually cut. The means required in such cases vary with the hardness of the mineral under examination. For the hardest minerals diamond powder is made use of in grinding; it is employed after the manner of the lapidary. (It may be mentioned here that the investigator will generally find it for his interests, both as regards time, money, and accuracy of results, to employ a lapidary to do this work for him.) The diamond powder is applied to a thin wheel of soft iron or copper, rotating on a lathe.

F'or minerals which are not so extremely hard. good emery may be used instead of dianond powder. It is merely necessary to apply the emery and water to the edge of the wheel as it revolves, the mineral being held firmly against. A neater and more advantageous method, where the amount of material is small, is the use of a fine saw, or better wire, mounted in a frame, and used with either diamond powder or emery moistened with water or oil. The crystal may be mounted in wax or otherwise, if very small ; sometimes a holder made of cork is convenient.

The direction in which the slice is to be cut is of the highest importance, and can ofter be indicated at first by is scratch across a plane of a crystal. In many cases it is more simple to griud on a surface in the proper direction, and this can be easily accomplished by holding the crystal against a fine-grained emery wheel rotating on a lathe. It can be held either in the fingers, or remented to a small piece of glass, for instance with Canada balsam.

Another way, more simple as demanding no instruments, is to make use of a flat piece of plate glass, not too small, on which the crystal is ground with moistened emery, being carefully moved about with the hand. In some cases a file, or even a knife, may be used, where the mineral in hand is soft.

Whatever method of grinding is adopted, it is necessary to exercise great care to bring the artificial surface into exactly the proper direction. This can be determined only as its inclina tions to existing crystalline planes, or cleavage surfaces, are measured, and practicaly it in necessar
ck and test what has been done. The parallel intersection
will often show the degree of correctness in the work. For purposes of measurement it is necessary to polish the artificial plane, or instead, a small piece of thin glass may be cemented on where the crystal is too small for the use of the hand-goniometer. It is of course necessary to know, before starting, the angle which the new plane will make with the natural planes which are already present. When one plane in the required direction has been obtained, it is a comparatively simple process to obtain a second parallel to it, though care must be exercised to attain accuracy.

The required section having been cut, it remains only to polish the surfaces. The means required differ so widely, according to the hardness of the mineral, that no fixed rule can be given. The most commonly used polishing powder is the English red, or colcothar, which may be used on the plate of glass, or leather surface, or on a revolving wheel covered with a soft cloth. In other cases oxide of tin or fine chalk is used; and again the simple plate of ground plass will answer the purpose without the use of any other means. As a rule, the hardest minerals take the polish most readily. Sometimes the only method practicable is to use small fragments of thin glass, adhering with balsam, by which transparency is obtained without polish, though errors are easily introduced by this means when sufficient care is not exercised.

The preparation of prisms for the measurement of the indices of refraction is practically much more difficult than that of a simple section, but in general the metnods are the same.

It is often advisable to examine a mineral microscopically when a slice in a particular direotion is not needed. In such cases use can be made of the methods employed in making rock slices. A revolving wheel of soft iron, vertical or horizontal, is employed, on the lateral surface of which the substance is ground with the use of emery moistened with water. A thin slice, or thin fragment broken off, is taken to commence with. First one surface is ground smooth and polished. The piece is then cemented to a little plate of thick glass with balsam, and the other side ground down parallel to the first, the grinding being continued until the required degree of transparency is obtained. Obviously when the section becomes thin and fragile, the coarse emery must be replaced with fine, and a considerable degree of care exercised. The section obtained is generally removed to another slip of glass and mounted with balsam under a thin glass cover.

The microscopic investigation of minerals, by means of thin slices, is of the highest importance, aside from optical investigations. Every chemical analysis should be preceded by such an examination to test the purity of the material in hand. Where a transparent section cannot be obtained, a single polished surface, examined by reflected light, will often exifice to decide the same point.
The valuable investigations of Vogelsang, Fischer, Rosenbusch, and others, referred to on pp. 108 to 111, show how many minerals, which at first glance seem perfectly pure, are found to enclose impurities considerable in variety and amount.

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## DIAPHANEITY; COLOR; LUSTRE.

There are certain characteristics belonging to all minerals alike, crystullized and non-crystallized, in their relation to light. These are :

1. Diapianeity; depending on the power of transmitting light.
2. Color; depending on the kind of light reflected or transmitted.
3. Lustre ; depending on the power and manner of reflecting light.

## 1. Diaphaneity.

The amount of light transmitted by a solid varies in intensity, or, in other words, of the light received more or less may be absorbed. The amount of absorption is a minimum in a perfectly transparent solid, as ice, while it is greatest in one which is opaque, as iron. The following terms are adopted to express the different degrees in the power of transmitting light:

Transparent: when the outline of an object seen throngh the mineral is perfectly distinct.

Subtransparent, or semi-transparent: when objects are seen, but the outlines are not distinct.

Translucent: when light is transinitted, but objects are not seen.
Subtranslucent: when merely the edges transmit light or are translucent.

When no light is transmitted, the mineral is said to be opaque. This is properly only a relative term, since no substance fails to transmit. some light, if made sufficiently thin. Magnetite is translucent in the Pennsbury mica. The recent researches of Prof. A. W. Wright have shown that by means of the electrical current the metals may be volatilized and deposited again on the sides of the surrounding glass tube. The layers thus formed are perfectly continuous, but so thin as to be transparent. By transmitted light the layer of gold thus obtained appears green, and that of silver a beautiful blue.

The property of diaphaneity occurs in the mineral kingdom, in every degree from nearly perfect opacity to a perfect transparency, and many minerals present, in their numerons varieties, nearly all the different shades.

The absorption of light in its relation to the axes of elasticity is spoken of on p. 165.

## 2. Color.

Cause of color.-The color of a substance depends upon its power of absorbing certain portions of the light, that is, certain rays of the spectrum; a yellow mineral, for instance, absorbs all the rays of the spectrum with the exception of the yellow. In general the color which the eye perceives is the result of the mixture of those rays which are not absorbed. All minerals may be divided into two classes: (1) those whose color is essential and belongs to the finest particles mechanically made ; (2) those whose color is non-essential and in the fine powder is different from what it is in the mass

Streak.-It is obvious from these distinctions that the color of the powder, or the streak, as it is called, is often a very important quality in distinguishing minerals. The streak is obtained by scratching the surface of the mineral with a knife or file, or still better, if not too hard, by rubbing it on an unpolished porcelain surface.

To the first class, mentioned above, belong the metals, and many metallic minerals; for instance, the streale of the black manganese oxides is black; that of hematite, which is red by transmitted light, is red, and so on. To the second class belong the silicates, and in fart the large part of all minerals. With them the color is often quite unessential, being generally due to small admixtures of some metallic oxide, to some carbon compound, or some foreign substance in a finely divided state. Most of these have a white or light-colored streak. For example, the streak of black, green, red, and blue tourmaline varies little from white.

## Varieties of Color.

The following eight colors have been selected as fundamental, to facilitate the employment of this character in the description of minerals: white, gray, black, blue, green, yellow, red, and brown.

## a. Metallic Colors.

1. Copper-red: native copper.-2. Bronze-yellow: pyrrhotite-3. Brassyellow.: chalcopyrite.-4. Gold-yellow.-5. Silver-white : native silver, less distinct in arsenopyrite.-6. Tin-white: mercury, cobaltite.-7. Lead-gray: galenite, molybdenite.-8. Steel-gray: nearly the color of fine-grained steel on a recent fracture; native platinum, and palladium.

## b. Non-metallic Colors.

A. White. 1. Snow-white: Carrara marble.-2. Reddish-white: some varieties of calcite and quartz.-3. Yellowish-white: some varieties of calcite and quartz.-4. Grayish-white: some varieties of calcite and quartz. -5. Greenish-white: talc.-6. Milk-white: white, slightly bluish; some chalcedony.
B. Gray. 1. Bluish-gray: gray, inclining to a dirty blue color.-2. Pearl-gray: gray, mixed with red and blue ; cerargyrite.-3. Smoke-gray: gray, with some brown ; flint.-4. Greenish-gray: gray, with some green; cat's eye, some varieties of talc.-5. Yellowish-gray: some varieties of compact limestone.-6. Ash-gray: the purest gray color; zoisite.
C. Blaç. 1. Grayish-black: black, mixed with gray (without any green, brown, or blue tints) ; basalt, Lydian stone.-2. Velvet-black: pure black; obsidian, black tourmaline.-3. Greenish-black: angite.-4 Brown ish-black: brown coal, lignite.-5. Bluish-black: black cobalt.
D. Blue. 1. Blackish-blue: dark varieties of azurite.-2. Azure-blue : a clear shade of bright blue; pale varieties of azurite, bright varieties of
lazulite.-3. Violet-blue: blue, mixed with red ; ametlyst, fluorite.-4 Lavender-blue: blue with some red and much gray.-5. Prussian-blue, or Berlin blue: pure blue; sapphire, cyanite-6. Smalt-blue: some varicties of gypsum.-7. Indigo-3lue : blue with black and green; blue tourma. line.-8. Sky-blue: pale blue with a little green ; it is called mountain blue by painters.
E. Green. 1. Verdigris-green: green inclining to blue; some feldspar (anazon-stone).-Celandine-green: green with blue and gray ; some varieties of talc and beryl. It is the color of the leaves of the celandine (Chelidonium majus).--3. Mountain-green: green with much blue; beryl.-4. Leek-green: green with some brown; the color of leaves of garlic; distinctly seen in prase, a variety of quartz.-5. Einerald-green: pure deep green ; emerald.-6. Apple-green: light green with some yellow ; chryso-prase.-7. Grass-green: bright green with more yellow ; green diallage.8. Pistachio-green: yellowish green with some brown ; epidote.-9. Aspa-ragus-green: pale green with much yellow; asparagus stone (apatite).一 10. Blackish-green: serpentine.-11. Olive-green: dark green with much brown and yellow; chrysolite.-12. Oil-green: the color of olive oil; beryl, pitchstone.-13. Siskin-green: light green, much inclining to yellow; uranite.
F. Yellow. 1. Sulphur-yellow: sulphur.-2. Straw-yellow: pale yellow; topaz.-3. Wax-yellow: grayish yellow with some brown; blende, opal.-4. Honey-yellow: yellow with some red and brown; calcite.-5. Lemon-yellow: sulphur, orpiment.-6. Ochre-yellow: yellow with brown; yellow ochre.-7. Wine-yellow: topaz and fluorite.-8. Cream-yellow: some varieties of lithomarge.-9. Orange-yellow: orpiment.
G. Red. 1. Aurora-red: red with much yellow; some realgar.-2. Myacinth-red: red with yellow and some brown; hyacinth garnet.-3. Brick-red: polyhalite, some jasper.-4. Scarlet-red: bright red with a tinge of yellow; cimnabar.-5. Blood-red: dark red with some yellow; pyrope-6. Flesh-red: feldspar.-7. Carmine-red: pure red; ruby sap-phire.-8. Rose-red: rose quartz.-9. C'rimson-red! ruby.-10. Peach-blossom-red: red with white and gray; lepidolite.-11. Columbine-red: deep red with some blue; garnet.-12. Cherry-red: dark red with some blue and brown: spinel, some jasper.-13. Brownish-red: jasper, limonite.
H. Brown. 1. Reddish-brown: garnet, zircon.-2. Clove-brown: brown with red and some blue; axinite.-3. Hair-brown: wood opal.-4. Broc-coli-brown: brown, with blue, red, and gray ; zireon.-5. Chestnut-brown: pure brown.-6. Yellowish-hrown: jasper.-7. Pinchbeck-brown: yellow-ish-brown, with a metallic or metallic-pearly lustre; several varieties of talc, bronzite.-8. Wood-lrown: color of old wood nearly rotten; some specimens of asbestus.-9. Liver-brown: brown, with some gray and green; jasper.-10. Blackish-brown: bituminous coal, brown coal.

## c. Peculiarities in the Arrangement of Colors.

Pluy of Colors.-An appearance of several prismatic colors in rapid succession on turning the mineral. This property belongs in perfection to the diamond; it is also observed in precious opal, and is most brilliant by candle-light.

Change of Colors.-Each particular color appears to pervade a larger space than in the play of colors, and the succession produced by tunning the mineral is less rapid; Ex. labradorite.

Opalescence.-A milky or pearly reflection from the interior of a specimen. Observed in some opal, and in cat's eye.

Iridescence.-Presenting prismatic colors in the interior of a crystal. The phenomena of the play of colors, iridescence, etc., are sometimes to be explained by the presence of minute foreign crystals, in parallel positions; more generally, however, they are caused by the presence of fine cleavage lamellæ, in the light reflected from which interference takes place, analogous to the well-known Newton's rings.

Tarnish.-A metallic surface is tarnished, when its color differs from that obtained by fracture; Ex. bornite. A surface possesses the steel tarnish, when it presents the superficial blue color of tempered steel ; Ex. columbite. The tarnish is irised, when it exhibits fixed prismatic colors ; Ex. hematite of Elba. These tarnish and iris colors of minerals are owing to a thin surface film, proceeding from different sources, either from a change in the surface of the mineral, or foreign incrustation; hydrated iron oxide, usually formed from pyrite, is one of the most common sources of it, and produces the colors on anthracite and hematite.

Asterism.-This name is given to the peculiar star-like rays of light observed in certain directions in some minerals by reflected or transmitted light. This is seen in the form of a six-rayed star in sapphire, and is also well shown in mica from South Burgess, Canada. In the former case it has been attributed by Volger to a repeated lamellar twinning; in the other case, by Rose, to the presence of minute inclosed crystals, which are a uniaxial mica, according to DesCloizeaux. Crystalline planes, which have been artificially etched, also sometimes exhibit asterism. In general the phenomenon is explained by Schrauf as caused by the interference of the light, due to fine striations or some other canse.
(Upon the above subjects, see Literature, p. 167.)

## Phosphorescence.

Phosphorescence,* or the emission of light by minerals, may be produced in different ways: by friction, by heat, or by exposure to light.

By.friction.-Light is readily evolved from quartz or white sugar by the friction of one piece against another, and merely the rapid motion of a feather will elicit it from some specimens of sphalerite. Friction, however, evolves light from a few only of the mineral species.

By heat.-Fluorite is highly phosphorescent at the temperature of $300^{\circ} \mathrm{F}$. Different varieties give off light of different colors; the chlorophane variety, an emerald-green light; others purple, blue, and reddish tints. This phosphorescence may be observed in a dark place, by subjecting the pulverized mineral to a heat below redness. Some varieties of white limestone or marble emit a yellow light.

[^23]By the application of heat, minerals lose their phosphorescent properties. But on passiry electricity through the calcined mineral, a more or less vivid light is produced at the time of the discharge, and subsequently the specimen when heated will often emit light as before. The ligh is usually of the same color as previous to calcination, but occasionally is quite different. It is in general less intense than that of the unaltered mineral, but is much increased by a repetition of the electric discharges, and in some varieties of fluorite it may he nearly or quite restored to its former brilliancy. It has also been found that some varieties of fluorite and some specimens of diamond, calcite, and apatite, which are not naturally phosphorescent, may be rendered so by means of electricity. Electricity will also increase the natural intensity of the phosphorescent light.

Light of the sun.-The only substance in which an exposure to the light of the sun produces very apparent phosphorescence is the diamond, and some specimens seem to be destitute of this power. This property is most striking after exposure to the blue rays of the spectrum, while in the red rays it is rapidly lost.

## Pleochroism.

Dichroism, Trichroism.-In addition to the general phenomena of color, which belong to all minerals alike, some of those which are crystallized show different colors under certain circumstances. This is due to the fact that in them the absorption of parts of the spectrum takes place unequally in different directions, and hence their color by transmitted light depends upon the direction in which they are viewed. This phenomenon is called in general pleochroism.

In uniaxial crystals it has been seen that, in consequence of their crystallographic symmetry, there are two distinct values for the velocity of light trausmitted by them, according as the vibrations take place, parallel or at right angles to the vertical axis. Similarly the crystal may exert different degrees of absorption upon the rays vibrating in these two directions. For example, a transparent crystal of zircon looked through in the direction of the vertical axis appears of a pinkish-brown color, while in a lateral direction the color is asparagus-green. This is because the rays (extraordinary) vibrating parallel to the axis are absorbed with the exception of those which together give the green color, and those vibrating laterally (ordinary) are absorbed except those which together appear pinkish-brown.

Again, all crystals of tourmaline in the direction of the vertical axis are opaque, since the ordinary ray, vibrating normal to the axis $\dot{c}$, is absorbed, while light-colored varieties, looked through laterally, are transparent, for the extraordinary ray, vibrating parallel to $\dot{c}$, is not absorbed ; the color differs in different varieties. Thus, all uniaxial crystals may be dichroic, or have two distinct axial colors.
Similarly all biaxial crystals may be trichroic. For the rays vibrating in the directions of the three axes of elasticity may be differently absorbed. For diaspore the three axial colors are azure-blue, wine-yellow, and violetblue. It will be understood that, while these three different colors are possible, they may not exist; or only two may be prominent, so that a biaxial mineral may be called dichroic.

In order to investigate the absorption-properties of any uniaxial or biaxial crystal, it is evident that sections must be obtained which are parallel to the
several axes of elasticity. Suppose that f. 410 represents a rectangular solid with its sides parallel to the three axes of elasticity of
 a biaxial crestal. In an orthorhombic crystal the faces are those of the three diametral planes or pinacoids; in a monoclinic crystal one side coincides with the clinopinacoid, the others are to be determined for each species. The light transmitted by this solid is examined by means of a single Nicol prism. Suppose, first, that the light transmitted by the parallelopiped (f. 410) in the direction of the vertical axis is to be examined. When the shorter diagonal of the Nicol coincides with the direction of the axis $\mathfrak{b}$, the colur observed belongs to that ray vibrating parallel to this direction ; when it coincides with the axis $\mathfrak{a}$, the color for the ray with vibrations parallel to $\mathfrak{a}$ is observed. In the same way the Nicol separates the different colored rays vibrating parallel to $\mathfrak{r}$ and $\mathfrak{a}$ respectively, when the light passes through in the direc tion of $b$.

So also finally when the section is looked through in the direction of the axis $\mathfrak{a}$, the colurs for the rays vibrating parallel to $b$ and $\mathfrak{c}$, respectively, are obtained. It is evident that the examination in two of the directions named will give the three possible colors.

For epidote, according to Klein, the colors for the three axial directions are:

1. Vibrations parallel to $\hbar$, brown (absorbed). 2. Vibrations parallel to $f$, green.

> a, yellow.
> 3. Vibrations parallel to $\mathfrak{f}$, green,
> b, brown (absorbed).

The colors observed by the eye alone are the resultants of the double set ut vibrations, in which the stronger color predominates; thus, in the above example, the plane, normal to $\mathfrak{c}$ is brown, to $\mathfrak{b}$, yellowish-green, to $\mathfrak{a}$, green. In any other direction in the crystal, the apparent color is the result of a mixture of those corresponding to the three directions of vibrations in different proportions. Dichroite is a striking example of the phenomenon of pleachroism.

An instrument called a dichroscope has been contrived by Haidinger for examining this property of crystals. An oblong rhombohedron of Iceland spar has a glass prism of $18^{\circ}$ cemented to each extremity. It is placed

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in a metallic cylindrical case, as in the figure, having a convex lens at one end, and a square hole at the other. On looking through it, the square hole appears double; one image belongs to the ordinary and the other to the extraordinary ray. When a pleochroic crystal is examined with it, by transmitted light, on revolving it, the two squares, at intervals of $90^{\circ}$ in the revo.

Intion, have different colors, corresponding to the direction of the vibrations of the ordinary and extraordinary ray in calcite. Since the two images ars situated side by side, a very slight difference of color is perceptible.

## Literature.-Pleochroism, Asterism, etc.

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_-_ Ueber das Schillern der Krystalltlächen; Pogg. lxx., 574, 1847; lxxi., 321; Ixxvi., 99, 1849.

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v. Kobell. Ueber Asterismus; Ber. Ak. München, 1863, 65.

Haushofer. Der Asterismus des Calcites; Ber. Ak. München, 1869.
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Sclirauf. Labradorit; Ber. Ak., Wien, lx., 1869.
Kosmann. Ueber das Schillern und den Dichroismus des Hypersthens; Jahrb. Min., 1860, 368, 532; 1871, 502.

Rose. Ueber den Asterismus der Krystallen; Ber. Ak. Berlin, 1862, 614 ; 1869, 344.

## 3. Lustre.

The lustre of minerals varies with the nature of their surfaces. A variation in the quantity of light reflected, produces different degrees of intensity of lustre; a variation in the nature of the reflecting surface produces different kinds of lustre.
A. The kinds of lustre recognized are as follows:

1. Metallic: the lnstre of metals. Imperfect metallic lustre is expressed by the term sub-metallic.
2. Adumantine: the lustre of the diamond: When also sub-metallic, it is termed metallic-adamantine. Ex. cerussite, pyrargyrite.
3. Vitreous: the lustre of broken glass. An imperfectly vitreous lustre is termed sub-vitreous. The vitreous and sub-vitreous lustres are the most common in the mineral kingdom. Quartz possesses the former in an eminent degree; calcite, often the latter.
4. Resinous: lustre of the yellow resins. Ex. opal, and some yellow varieties of sphalerite.
5. Pearly: like pearl. Ex. talc, brucite, stilbite, etc. When united with sub-metallic, as in hypersthenite, the term metallic-pearly is used.
6. Silky: like silk; it is the result of a fibrous structure. Ex. fibrous calcite, fibrous gypsum.
$B$. The degrees of intensity are denominated as follows:
7. Splendent : reflecting with brilliancy and giving well-defined images. Ex. hematite, cassiterite.
8. Shining: producing an image by reflection, but not one well defined. Ex. celestite.
9. Glistening: affording a general reflection from the surface, but no image. Ex. talc, chalcopyrite.
10. Glimmering: affording imperfect reflection, and apparently from points over the surface. Ex. flint, chalcedony.

A mineral is said to be dull when there is a total absence of lustre. Ex chalk, the ochres, kaolin

The true difference between metallic and vitreous lustre is duc to the effect which the different surfaces have upon the reflected light; in general, the lustre is produced by the union of two simultaneous impressions made upon the eye. If the light reflected from a metallic surface be examined by a Nicol prism (or the dichroscope of Haidinger), it will be found that both rays, that vibrating in the plane of incidence and that whose vibrations are normal to it, are alike, each having the color of the material, only differing a little in brilliancy; on the contrary, of the light reflected by a vitreous substance, those rays whose vibrations are at right angles to the plane of incidence are more or less polarized, and are colorless, while those whose vibrations are in this plane, having penetrated somewhat into the medium and suffered some absorption, show the color of the substance itself. A plate of red glass thus examined will show a colorless and a red image. Adamantine lustre occupies a position between the others.

The different degrees and kinds of lustre are often exhibited differently by unlike faces or the same crystal, but always similarly by like faces. The lateral faces of a right square prism may thus differ from a terminal, and in the right rectangular prism the lateral faces also may differ from one another. For example, the basal plane of apophyllite has a pearly lustre wanting in the prismatic planes. The surface of a cleavage plane in foliated minerals, very commonly differs in lustre from the sides, and in some cases the latter are vitreous, while the former is pearly. As shown by Haidinger, only the vitreous, adamantine, and metallic lustres belong to faces perfectly smooth and pure. In the first, the index of refraction of the mineral is $1.3-1.8$; in the second, $1.9-2 \cdot 5$; in the third, about $2 \cdot 5$. The pearly lustre is a result of reflection from numberless lamellæ or lines within a translucent mineral, as long since observed by Breithaupt.

## IV. HEAT.

The expansion of crystallized minerals by heat depends, as directly as their optical properties, on the symmetry of their molecular structure as shown in their crystalline form. The same three classes as before are distinguished:
A. Isometric crystals, where the expansion is in all directions alike.
B. Isodiametric crystals, of the tetragonal and hexagonal systems. Expansion vertically unlike that laterally, but in all lateral directions alike.
C. Anisometric, of the orthorhombic, monoclinic, and triclinic systems. Expansion unlike in the three axial directions. The expansion by heat in the case of crystals may serve to alter the angles of the form, but it has been shown that the zone relations and the crystalline system remain constant.
Mitscherlich found that in calcite there was a diminution of $8^{\prime} 37^{\prime \prime}$ in the angle of the
rhombohedron, on passing from $32^{\circ}$ to $212^{\circ} \mathrm{F}$., the form thus approaching that of a cube, as
the temperature increased. Dolomite, in the same range of temperature, diminishes $4^{\prime} 46^{\prime \prime}$;
and in aragonite, between $63^{\circ}$ and $212^{\circ} \mathrm{F}$., the angle of the prism diminishes $2^{\prime} 46^{\prime \prime}$, and
$1-\check{\imath}: 1-\iota^{\breve{\prime}}$ increases $5^{\prime} 30^{\prime \prime}$; in gypsum, $I: i-i$ is increased $5^{\prime} 24^{\prime \prime}, I: 1,4^{\prime} 12^{\prime \prime}$, and $1-i: i-i$ is
diminished $7^{\prime} 24^{\prime \prime}$. In some rhombohedrons, as of calcite, the vertical axis is lengthened
(and the lateral shortened), while in others, like quartz, the reverse is true. The variation
is such either way that the double refraction is diminished with the increase of heat; for
calcite possesses negative double refraction, and quartz, positive.

The conductive power of a crystal depends, as does expansion, on the aymmetry of its crystalline form; this is also true of its power of trans.
mitting or absorbing heat. It follows, moreover, from the analogous nature of heat and light, that heat rays are polarized by reflection, and by transmission in anisotrope media, in the same way as the rays of light. These subjects, considered solely in their relation to Mineralogy, are of minor importance; they belong to works on Physics, and, reference may be made to those whose titles are given in the Introduction, as also to the works of Schrauf and Groth.
The change in the optical properties of crystals produced by heat has already been noticed (p. 151).

## V. ELECTRICITY-MAGNETISM.

The electric and magnetic characters of crystals, as their relations to heat, bear but slightly upon the science of mineralogy, although of high interest to the student of physics.

Frictional electricity.-The development of electricity by friction is a familiar fact. All minerals become electric by friction, although the degree to which this is manifested depends upon their conducting or nonconducting power. There is no line of distinction among minerals, dividing them into positively electric and negatively electric; for both kinds of electricity may be presented by different varieties of the same species, and by the same variety in different states. The gems are positively electric only when polished; the diamond alone among them exhibits positive electricity whether polished or not. The time of retaining electric excitement is widely different in different species, and topaz is remarkable for continuing excited many hours.

Pressure also develops electricity in many minerals; calcite and topaz are examples.

Pyro-electricity.-A decided change of temperature, throngh heat or cold, develops electricity in a large number of minerals, which are hence called pyro-electric. This property is most decided, and was first observed in a series of minerals which are hemimorphic or hemihedral in their development. The electricity in these minerals is of opposite character in the parts dissimilarly modified. Thus in tourmaline and calamine, the erystals of which are often differently modified at the two extremities, positive and negative electricity are developed at these extremities or poles respectively. When the extremity becomes positive on heating it has been called the analogue pole, and when it becomes negative, it has been called the antilogue. The names were given by Rose and Riess, who investigated these phenomena. For a change of temperature in the opposite direction, that is, cooling, the reverse electrical effect is observed.

Boracite, on whose crystals the + and - tetrahedrons often occur, shows by heating the positive electricity for the faces of one tetrahedron and the negative for those of the other.

Further investigations by Hankel and others (see Literature) have extended the subject and shown that the phenomena of pyro-electricity belong to the crystals of a large number of species. Moreover, it is not, as cnce supposed, essentially connected with hemihedral development. The number of poles, too, may be more than two, that is, the points at which posi
tive and negative electricity is developed. Thus for prehnite there is a large series of such poles, distributed over the surface of a crystal. The investigations of Hankel have shown in general, that in crystals not hemihedrally developed, the same electricity is developed at both extremities of the same axis, and the distinction between positive and negaiive electricity is only shown by reference to the different crystallographic axes; on synmetrically formed crystals of the isodiannetric class the electricity is the same in all lateral directions, that is, on all prismatic planes, while different at the extremities of the vertical axis.

Thermo-electricity. When two different metals are brought into contact, a stream of electricity passes from one to the other. If one is heated the effect is more decided and is sufficient to deflect more or less vigoronsly the needle of a galvanometer. According to the direction of the current produced by the different inetallic substances, they are arranged in a thermo-electrical series; the extremes are occupied by antimony $(+)$ and bismuth ( - ), the electrical strean passing from bismuth to antimony.

This subject is so far important for mineralogy, as it was shown by Bunsen that the natural metallic sulphides stand further off in the series than antimony and bismuth, and consequently by them a stronger stream is produced. The thermo-electrical relations of a large number of minerals was determined by Flight (Ann. Ch. Pharm., exxxvi.).

It was early observed that some minerals have varieties which are both + and -. This fact was made use of by Rose to show a relation between the plus and minus hemihedral varieties of pyrite and cobaltite. The later investigations of Schrauf and Dana have shown, however, that the same peculiarity belongs also to glancodot, tetradymite, skutterndite, danaite, and other minerals, and it is demonstrated by them that it camot be dependent upon crystalline form, but, on the contrary, upon chemical compusition.

Magnetism. - The magnetic properties of crystals are theoretically of interest, since they, too, like the optical and thermic, are directly dependent upon the form ; hence, with relation to magnetisin they gronp themselves into the same three classes before referred to.

All substances are divided into two classes, the paramagnetic and diamagnetic, according as they are attracted or repelled by the poles of a mag: net. For purposes of experinent the substance in question, in the form of a rod, is suspended between the poles of the magnet, being movable on a horizontal axis. If of the first class, it will take a position parullel, and if of the second class, transverse, to the magnetic axis.

By the use of a sphere it is possible to determine the relative amount of magnetic induction in different directions of the same substance. Experiment has shown that in isometric crystals the magnetism is alike in all directions ; in those optically uniaxial, that there is a direction of maximum and, normal to it, one of minimum magnetism; in biaxial crystals, that there are three unequal axes of magnetism, the position of which may be determined.

A few minerals have the power of exerting a sensible influence upon the magnetic needle, and are hence said to be magnetic. This is true of magnetite and pyrrhotite (magnetic pyrites) in particular, also of franklinite, almandite, and other minerals, containing considerable iron protoxide ( $\mathrm{F} \in \mathrm{O}$ ). When such minerals in one part attract and in another repel the poles of
the magnet, they are said to possess polarity. This is true of the variety of magnetite called in popular language loadstone.

## Literature.-Electricity.*

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On magnetism reference may be made to Faraday (Experimental Researches); Tyndall, Phil. Mag.; Knoblauch and Tyndall, Pogg., lxxxi., 481, 498 ; lxxxiii., 384 ; Pflücker, Pogg., Ixxii., 315 ; lxxvi., 576 ; lxxvii., 417 ; lxxxvi., 1; Grailich u. von Lang, Ber. Ak., Wien, xxxii., 43 ; xxxiii., 439, etc., etc.

## VI. TASTE AND ODOR.

In their action upon the senses a few minerals possess taste, and others under some circumstances give off odor.

Taste belongs only to soluble minerals. The different kinds of taste adopted for reference are as follows:

1. Astringent; the taste of vitriol.
2. Sweetish astringent ; taste of alum.
3. Suline; taste of common salt.
4. Allaline ; taste of soda.
5. C'ooling; taste of saltpeter.
6. Bitter ; taste of epsom salts.
7. Sour: taste of sulphuric acid.

Odor.-Excepting a few gaseous and soluble species, minerals in the dry unchanged state do not give off odor. By friction, moistening with the breath, and the elimination of some volatile ingredient by heat or acids, odors are sometimes obtained which are thus designated:

1. Alliaceous ; the odor of garlic. Friction of arsenical iron elicits this odor; it may also be obtained from arsenical compounds, by means of heat.
2. Horse-radish odor; the odor of decaying horse-radish. This odor is strongly perceived when the ores of selenium are heated.
3. Sulphureous ; friction elicits this odor from pyrite and heat from many sulphides.
4. Bituminous ; the odor of bitumen.
5. Fetid ; the odor of sulphuretted hydrogen or rotten eggs. It is elicited by friction from some varieties of quartz and limestone.
6. Argillaceous ; the odor of moistened clay. It is obtained from ser-
pentine and some allied minerals, after moistening them with the breath; others, as pyrargillite, afford it when heated.

The Feed is a character which is occasionally of some importance ; it is said to be smooth (sepiolite), greasy (talc), harsh, or meagre, etc. Some minerals, in consequence of their hygroscopic character, adhere to the tongue, when brought in contact with it.

## SECTION II.-SUPPLEMENTARY CHAPTER.

I. COHESION AND ELASTICITY (pp. 119 to 122).

The etching-figures (Aetzfiguren) produced by the action of appropriate solvents upon the surfaces of crystals have been further investigated in the case of a considerable number of minerals, and the results have in some cases served to throw light upon the question as to which crystalline system a given species belongs. See the investigations of BaUMHAUER of the etching-figures of lepidolite, tourmaline, topaz, calamme, Jahrb. Min., 1876, i. ; pyromorphite, mimetite, vanadinite, ib., $18 \% 6,411$; of adularia, albite, fluorite, ib., 1876,602 ; of leucite, Z. Krvst., i., $25 \%$, $18 \% \%$; quartz, ib., ii., $11 \%, 1878$; mica (zinnwaldite), ib., iii., 113 , 1878 ; boracite, ib., iii., $33 \%$, $18 \% 9$; perofskite, ib., iv., 187, 1879 ; nephelite, ib., vi., 209, 188\%. (For earlier papers giving results of etching experiments on muscovite, garnet, linnæite, biotite, epidote, apatite, gypsum, in Ber. Ak. München, 1874, $245 ; 1876,99$.$) On the etching-figures of alum, see Fr. Kuocke, Z.$ Kryst., ii., 126, 1878 ; of the different micas, F. J. Wirk, Oefv. Finsk. Vet. Soc., xxii., 1880.

On the artificial twins (twinning-plane $-\frac{1}{2} R$ ) of calcite produced by simple pressure with a knife-blade on the obtuse edge of a cleavage fragment, see Baumhauer, Zeitschr. Kryst., iii., 588, 1879 ; Brezina, ib., iv., 518,1880 . The fragment should have a prismatic form, say $6-8 \mathrm{~mm}$. in length and $3-6 \mathrm{~mm}$. in breadth, and be placed with the obtuse edge on a firm horizontal support. The blade of an ordinary table-knife is then applied to the other obtuse edge, as at a (f. 412a), and pressed gradually and firmly down. The result is that the portion of the crystal lying between $a$ and $b$ is reversed in position, as if twinned parallel to the horizontal plane $-\frac{1}{2} R$. The twinning surface, $g c e$, is perfectly smooth, and the re-entrant angle corresponds very exactly with that required by theory (Brezina). Earlier observations by Pfaff and Reusch have shown that twin lamellæ $\left(-\frac{1}{2} R\right)$ may be produced in a cleavage mass of calcite of prismatic form, by simple pressure exerted perpendicular to a straight terminal plane. Such twinning lamellæ are often observed in thin sections of a crystalline limestone when examined in polarized light under the microscope.

On the application of the fracture-figures (Schlagfiguren) in the optical examination of the mica species see Bauer, ZS. G. Ges.: xxvi., 137, 1874 (for earlier papers see p. 122) ; 'Tschermak, Z. Kryst., ii., 14, 187\%. On the occurrence of Gleitflächen on galena see Bauer, Jahrb. Min., 1882, i., 183.

## II. SPECIFIC GRAVITY (pp. 123, 124).

Use of a Solution of high Specific Gravity.-A solution of mercuric iodide in potassium iodide $\left(\mathrm{Hg}_{2} \mathrm{I}\right.$ in KI$)$ affords a means of readily obtaining the specific gravity of any mineral not acted upon by it chemically,
and for which G. $<3.1$; and also of separating from each other mincrals of different densities, when intimately mixed in the form of small fragments. The solution is called the Sonstadt solution, having been first proposed by E. Sonstadt in 1873 (Chem. News, xxix., 127) ; its application for the above objects was proposed by Church in $187 \%$ (Min. Mag., i., 237) ; and the method elaborated by Thoulet in $18 \% 8$ (C. R., Feb. 18. 1878 ; Bull. Soc. Min., ii. 17, 189, 1879), and later by Goldschmidt (J. Min., Beil.Bd., i., 179, 1881).

The solution is prepared (Goldschmidt) as follows : The KI and $\mathrm{Hg}_{2} \mathrm{I}$ are taken in the ratio of 1:1.239, and introduced into a volume of water slightly greater than is required to dissolve them (saty 80 cc . to 500 gr . of the salts) ; the solution is then filtered in the usual way and afterward evaporated down in.a porcelain vessel, over a water-bath, until a crystalline scum begins to form, or when a fragment of tourmaline ( $\mathrm{G}_{\mathrm{o}}=3.1$ ) floats; on cooling, the solution has its maximum density. If the mercuric iodide is not quite pure a small quantity in excess of that required by the above ratio must be taken. The highest specific gravity for the solution obtained by Goldschmidt was $3 \cdot 196$, a solution in which fluorite floats. This maximum is not quite constant, varying with the moisture of the atmosphere and with the temperature.

The method of using the solution for obtaining the specitic gravity of small fragments of any mineral is, according to Goldschmidt, as follows: The fragments are introduced into a tall beaker, say 40 cc. capacity, with a portion of the concentrated solution; then water is added drop by drop (or a dilute solution of the same for high densities) from a burette, until the frag-. ments, after being agitated, are just suspended, and remain so without either rising or falling. This process requires care and precision, since the principal error to which the method is liable is involved here. The solution is now introduced into a little glass flask, graduated say to hold just 25 cc., and this amount having been exactly measured off, the weight is taken; then the solution is poured back into the original beaker and the fact noted whether the fragments still remain suspended ; then introduced again into the flask and weighed, and so a third time. The average result of the three weighings, diminished by the known weight of the flask and divided by 25 , gives the specific gravity. The exact measurement of the 25 cc . is a matter of importance, and is most easily accomplished by adding at first a little more than enough and then removing the excess by a capillary tube or a piece of filter paper ; the reading is best taken from the lower edge of the meniscus. It is not necessary to clean and dry the flask each time. The weighing need not be very accurate, as an error of 25 mgr . only involves a change of a unit in the third decimal place (.001). The describer readily obtained results accurate to three decimals. The advantages of the method are that it is readily applicable in the case of small fragments (dust is to be avoided), it is easily used, and any want of homogeneity in the mineral makes itself at once apparent.

This solution is also most useful in affording a means of separating mechanically different minerals when intimately mixed together ; as, for example, in a fine-grained rock. For this purpose the rock must first be pulverized in a steel mortar, then put through a sieve, or better, through several, so as to obtain a series of sets of fragments of different size; the dust is rejected. The fragments should be examined under the microscope, to see that they are homogeneous; the largest fragments satisfying this condition will give the best results.

According to Thoulet the best method of procedure is to first determine the density of the fragments approximately by inserting typical ones in a series of samples of the solution of gradually increasing density. This point determined, some 60 cc . of the concentrated solution are introduced into the tube, $A$, and 1 or 2 grams of the weighed fragments added. Then the tightly-fitting rubber cork with the tube, $F$, is inserted ; the tube, $F$, is connected by a rubher tube with an air pump, and the air bubbles are in this way removed from the powder. The heavy parts of the mixture fall to the bottom, and are removed by opening the stop-cock at $C$, and are washed out by use of the tube, $B$; the other fragments float. Now a quantity of distilled water is added in order so to dilute the solution as to cause the next heavier portions to sink, as determined by the equation

$$
v_{1}=\frac{v(D-\Delta)}{\Delta-1}
$$

where $v=$ volume of the solution, $D$ its specific gravity, $v_{1}$ the volume of the water, and $\Delta$ the density desired. The cock at $D$ is shat and that at $C$ opened and air blown through the side tube, so as to mix the solution thoroughly ; th:en the original operation is repeated, and so on.

Goldschmidt recommends the following method of procedure. The separation is conducted in a small slender beaker of about 40-50 cc. capacity. Instead of the series of standard solutions (the density of which is liable to alter) a series of minerals of known specific gravity are used as indicators; by means of them it
 is easy to determine the limits as to density which are required to make the separation desired, the constituent minerals having been determined by the microscope. For example, suppose it to be desired to separate augite, hornblende, oligoclase, and orthoclase ; labradorite and albite are taken as indicators. Augite falls at once in the concentrated solution ; if diluted till the labradorite sinks, all the hornblende goes down ; before or with the albite the oligoclase sinks, and the orthoclase is left suspended. By the use of the 25 cc . flask, the exact specific gravity in each case can be obtained if desired. The operation of separation goes on as follows : The rock powder and the indicators are inserted with say 30 cc . of the concentrated solution into the beaker spoken of, then the whole is stirred vigorously and allowed to settle, and the lighter part decanted off. The heavier part which has settled is removed with a jet from a wash bottle, without disturbing the lighter fragments adhering to the upper part of the beaker. The latter are subsequently removed, washed, dried, again washed in the solution, and added to the rest for the further separation. If the separations accomplished in this way are not complete, they may be repeated most conveniently with the Thoulet apparatus. Under favorable conditions, and if the manipulation is skilful, the separation can be accomplished with considerable exactness. For the best results the process must be repeated several times.

Thoulet recommends also (l. c.) this method of determining the specific gravity of small fragments of minerals. A float of wax (inclosing any suitable solid body) is made with a specific gravity of from 1 to 2. The frag-
ments of the mineral are lightly pressed into the wax float, and this introduced into the Sonstadt solution, of such strength that the float remains in equilibrium at any level. If $P, V, D$ are respectively the weight, volume, and density of the float alone $\left(V=\frac{P}{D}\right)$ and $p, v, d$ the same values for the fragments alone $\left(v=\frac{p}{d}\right)$ and finally $\Delta$ the density of the liquid in which the loaded float is in equilibrium ; then

$$
\Delta=\frac{P+p}{V+\frac{p}{d}} \quad \text { or } \quad d=\frac{p \Delta}{P+p-\Delta V}
$$

Breon has proposed (Bull. Soc. Min., iii., 46, 1880) the following method for separating different minerals intimately mixed, which is applicable in cases where their density is greater than that of the Sonstadt solution. Lead chloride and zinc chloride, in appropriate proportions, are fused together (at $400^{\circ}$ C.) and by this means a transparent or translucent solution is obtained of high specific gravity. Briefly, the method of procedure is as follows: A conical tube of glass is taken, of about 12 to 15 cc. capacity ; this will allow of the treatment of 4 or 5 grams of the mixed minerals. The chlorides of lead and zinc, in approximately the proper proportions, are placed in the glass tube and this, surrounded by sand, inserted in a platinum crucible. On the application of heat the zinc chloride fuses first, but finally a homogeneous mixture of the two liquids is obtained. Now, little by little, the mineral fragments are introduced and the liquid stirred; then on allowing it to stand for a moment the heavier particles sink to the bottom and the lighter ones float. The tube is now removed from its sand bath and cooled rapidly. When solidified but still hot the glass may be plunged into cold water, in which case it will be broken and the fragments can be removed, so that the fused mass within can be obtained free. Subsequently the fragments in the upper and lower parts of the mass can be separated by solution in water to which a little acetic acid has been added. The author has operated on minerals varying from wolframite (G. $=7.5$ ) to beryl ( $G .=2.7$ ), and in some samples of sand has separated as many as 12 constituent minerals.
D. Klein (Bull. Soc. Min., jv., 149, 1881) has proposed to use one of the boro-tungstate salts in the place of the Sonstadt \%olution for the separation of minerals whose specific gravity is as high as 3.6 . The most suitable salt for this purpose is the cadmium compound, $\mathrm{H}_{4} \mathrm{Cd}_{2} \mathrm{~B}_{2} \mathrm{~W}_{0} \mathrm{O}_{34}+16$ aq. It dissolves at $22^{\circ} \mathrm{C}$. in about $\frac{1}{10}$ its weight of water, and crystallizes out both on evaporation and cooling. At $75^{\circ} \mathrm{C}$. it melts (best over a water-bath) in its water of crystallization to a yellow liquid, on the surface of which a spinel crystal ( $G .=3 \cdot 55$ ) floats. By the application of the Thoulet apparatus (see above), so arranged as to allow of the application of heat, solutions of any specific gravity, hot or cold, from 1 to 3.6 , can be obtained. A number of common minerals (e. g. chrysolite, epidote, vesuvianite, some varieties of amphibole and mica) can be separated by the use of this liquid, while the Sonstadt solution is inapplicable. The fragments under examination must be free from the carbonates of calcium or magnesium, which decompose the boro-tungstate of cadmium.
III. LIGHT (pp. 125-168).

## Measurement of Indices of Fefraction.

For the determination of the indices of refraction of crystallized minerals, various improvements have been made in former methods and some new methods devised.

Use of the Horizontal Goniometer.-The ordinary method for determining the index of refraction, requiring the observation of the angle of minimum deviation ( $\delta$ ) of a light-ray on passing through a prism of the given material, having a known angle $(\alpha)$, and with its edge cut in the proper direction, has already been mentioned (p. 128). The two measurements required in this case can be readily made with the horizontal goniometer of Fuess, described on p. 115. In this instrument the collimator is stationary, being fastened to a leg of the tripod support, but the observing telescope with the verniers moves freely. In the use for this object the graduated circle is to be clamped, and the screw attachments connected with the axis carrying the support, and the vernier circle and observing telescope are to be loosened. The method of observation requires no further explanation (see also pp. 141, 150).

Total Reflectrometer.-F. Kohlrausch has shown (Wied. Ann., iv., 1, 1878) that the principle of total reflection (p. 128) may be made use of to determine the index of refraction in cases where other methods are inapplicable. No prism is required, but only a small fragment having a single polished surface; this may be cut in any direction for an isotrope medium; it should be parallel to the vertical axis in a uniaxial crystal, and perpendicular to the acute bisectrix with a biaxial crystal. The arrangements required are, in their simplest form, a wide-monthed bottle filled with carbon disulphide (refractive index 1.6); the top of this is formed by a fixed graduated circle, and a vertical rod, with a vernier attached, passes through the plate and carries the crystal section on its extremity, immersed in the liquid. The angle through which the crystal surface lying in the axis is turned is thus measured in the same way as in f. 412H, by the vernier on the stationary graduated circle. The front of the bottle is made of a piece of plate glass, and through this passes the horizontal observing telescope, arranged for parallel light. The rest of the surface of the bottle is covered with tissue-paper, through which the diffuse illumination from say a sodium flame has access; the rear of the bottle is suitably darkened. When now the observer looks through the telescope, at the same time turning the axis carrying the crystal section, he will finally see, if the source of illumination is in a proper oblique direction, a sharp line marking the limit of the total reflection. The angle is then measured off on the graduated circle, when this line coincides with one of the spider lines of the telescope. Now the crystal is turned in the opposite direction, and the angle again read off. Half the observed angle ( $2 \alpha$ ) is the angle of total reflection ; if $n$ is the refractive index of the carbon disulphide, then the required refractive index is equal to

## $n \sin \alpha$.

Under favorable conditions the results are accurate to four decimal places. This method is limited, of course, to substances whose refractive index is less than that of the liquid medium with which the bottle is filled. With a sec-
tion of a uniaxial crystal, whose surface is must conveniently parallel to the vertical axis, the method is essentially the same. The section is so placed that in it the direction normal to the optic axis is horizontal. The light will be here separated into two rays, having separate limiting surfaces, and with a Nicol prism it is easy to determine which of them corresponds to the vibrations parallel and perpendicular, respectively, to the optic axis. For biaxial crystals the surface should be normal to the acute bisectrix. This will give by actual observation the values of $\alpha$ and $\gamma$, and if $2 E$, the apparent axial angle in air, is known, then $\beta$, the mean index can be calculated (see p. 150). Instead of carbon disulphide the Sonstadt solution, with $n=1.73$, can be employed. The total reflectrometer of Kohlrausch has been adapted in practical form to the horizontal goniometer (f. 3\%2A) of Fuess (see Liebisch, Ber. Ges. Nat. Fr. Berlin, Dec. 16, 1879). Klein has suggested some improvements (J. Min., 1879, 880), and Bauer (J. Min., 188\%, i., 132) has shown how the method can be simply applied to the instrument for the measurement of the optic axial angle (f. 412H), and without its modification in any important respect.

Quincke (abstract in Z. Kryst., iv., 540) has described another method for obtaining the refractive index of a substance on the principle of total reflection. In a word, it consists in observing on a spectrometer the limiting angle of total reflection for a plane section of the substance to be investigated, brought with oil of cassia between two flint glass prisms.
Sorby (Proc. Roy. Soc., xxvi., 384 ; Min. Mag., i., 97 , 194 ; ii., 1, 103) has developed the method of obtaining the refractive index of a transparent medium, first described by Duke de Chaulnes (1767), and has shown that under suitable conditions it allows of determinations being made with considerable accuracy. This method consists in observing the distance ( $d$ ) which the focal distance of the objective is changed when a plane-plane plate of known thickness $(t)$ is introduced perpendicular to the axis of the microscope between the objective and the focal point-here

$$
\mu=\frac{t}{t-d}
$$

Sorby makes use of a glass micrometer, upon which two systems of lines perpendicular to each other are ruled. The micrometer screw at $g$, in the Rosenbusch microscope (f. 41\%к, p. 181), makes it possible to measure the distance through which the tube is to be raised and lowered down to .001 mm . ; cousequently both $t$ and $d$ can be obtained with a high degree of accuracy.

BaUEr has shown that the indices of refraction may be obtained with considerable accuracy from measurements, in the plane of the axes, of the distances between the black rings in the interference figures as seen in homogeneous light. The relation between these distances and the optical axes of elasticity was established by Neumann (Pogg. Ann., xxxiii., 257, 1834). Bauer has made use of this method in the case of muscovite (Ber. Ak. Berlin, 1877, 704). He has also developed the same method as applied to uniaxial crystals and employed it in the case of brucite (ib., 1581, 958).

## Polarization Instruments.

Polariscope.-The earlier forms of polariscope for converging and for par-
allel light, as arranged by Groth and constructed by Fuess, are shown in figs. 384, 385, p. 134. The more recently constructed instruments (see Liebisch, l. c., p. 342 et seq.), with some important improvements, are shown in f. 412 c and f. 412 d . The lower tube, $f$, containing the analyzer, has about it a collar, $f^{\prime}$ (see details, figure 412F), with a triangular projection on the upper edge; this fits into one of two corresponding triangular depressions ( $0^{\circ}$ and $45^{\circ}$ ) in the surrounding tube, $g$. . This serves to fix the position of the tube, that is, of the vibration-plane of the enclosed Nicol, with reference to the fixed arm, $B$, to which the verniers are attached, so that the principal section of the Nicol either coincides with, or makes an angle of $45^{\circ}$ with the $0^{\circ}$ line of the verniers. The circle, $i$, is graduated to $1^{\circ}$, and with the vernier gives readings to $2^{\prime}$; the section to be examined is supported at $k$. A similar collar, $u$, surronnds the upper tube, $v$, by which the position of the micrometer (at $r$ ) (this micrometer consists of two lines at right angles, one of which is graduated) can also be fixed relatively to the vernier so that the graduated line of the micrometer is perpendicular to the plane through the axis of the instrument and the zero of the vernier. The tube above carrying the Nicol has at $s$ a graduated circle which shows the relative directions of the vibration-planes of the two Nicols. The lenses at $n$ and $o$


Stauroscope-Calderon's Plate.-The stauroscope is essentially the same instrument as that mentioned in f. 385. Instead, however, of employing the Brezina interference-plate of calcite, a double plate is used, as suggested by Calderon (Z. Kryst., ii., 68). This plate is, in fact, an artificial twin, and is made as follows: A calcite rhombohedron is cut through along the shorter diagonal ; from each half a wedge-shaped portion is cut away and the two surfaces thus produced, after being polished, are cemented together. A plane-plane plate is

## 412a.

 then cut from this (compare figure) by grinding away the angles as indicated ; this plate is divided into two halves by the line of separation of the artificial twin. Such a plate is very sensitive, and allows of very exact observations. It is placed at $m$ (f. 412D), and when the arrangements are completed the dividing line of the calcite exactly coincides with a vibration-plane of one of the two Nicols. A diaphragm is placed above with holes of varying size according to the minuteness of the crystal to be examined. The stauroscopic determinations made by Calderon showed an error of only $3^{\prime}$ to $7^{7}$.

Axial-angle Instrument (see p. 148). -The instrument for the measurement of the angle of the optic axes is in principle essentially that of Des Cloizeaux, but in the details of the construction various improvements have

been introduced (see f. 412 H ). The same arrangement of adjustable collars at $u^{\prime}$ and $f^{\prime}$ is employed as in the other instruments, to fix the position of the principal sections of the Nicols relatively to the plane passing through the axis of the observing telescope and the axis of rotation. Instead of the straight rod in f. 401, in the pincers at the extremity of which the crystal section is

held, there is here an arrangement consisting of two concentric tubes, turning independently, but so as to be clamped at $e$. The adjustable disk having a horizontal motion at $F$, and the spherical segment at $H$ (Petzval support) allow of the section being both centered and adjusted.

Polariscope of Adams-Schneider.-A polariscope of peculiar construction, giving a very large field of view, and at the same time allowing of the measurement of the axial angle, was proposed in $18 \% 5$ by Adams (Phil. Mag., IV., l., p. 13, $18 \%$; V., viii., $2 \% 5$ ). The same instrument has been further developed by Schneider (Carl. Rep., xv., '744), and is also described by Becke (Min. Petr. Mitth., ii., 430, 1879). The peculiarity of the instrument consists in this, that the middle plano-convex lenses which ordinarily are fixed to the upper and lower lens systems, respectively (see $0,0,0$, and $n, n$, $n$, in f. 412 c ), are here separated from the others in a common support, and together form a sphere. The course of the light-rays will be always the same, however the sphere is rotated about its fixed centre. Between the semispherical lenses a space is left, and here is introduced the section to be examined, which, turning with the surrounding lenses, can obviously be made to take any desired position with reference to the axis of the instrument. An appropriate arrangement makes it possible to measure the angle through which the section must be rotated to bring first one and then the second optic axis in coincidence with the axis of the instrument. The advantages of the instrument consist in the fact that the field of view is very large, and at the same time it allows of placing the section in any desired position relatively to the axis. Moreover, the angle measured is the apparent angle for the glass of which the lenses are made, so that the axes are visible in cases where this would not be the case, because of total reflection, either in air or in oil.

Polarization-Microscope.-The investigation of the form and optical properties of minerals when in microscopic form, as they occur, for example, in rocks of fine crystalline structure, has been much facilitated by the use of instruments specially adapted for this purpose. The most serviceable polarizing microscope, for gencral use, is that described by Rosenbusch (Jahrb. Min., 1876,504 ), and made by R. Fuess, of Berlin. A sectional view is given in f. 412 K . The essential arrangements are as follows: The coarse adjustment of the tube carrying the eye-piece and objective is accomplished by

412 L .
 the hand, the tube sliding freely in the support, $p$. The fine adjustment is made by the screw, $g$; the screw-head is graduated and turns about a fixed index attached to $p$, by this means the distance through which the tube is raised or lowered can be measured to $0 \cdot 001 \mathrm{~mm}$.; this is important in determining the indices of refraction by the De Chaulnes-Sorby method (see p. 178). The polarizing prism (Razumorsky) is placed below the stage at $r$, in a support, with a graduated circle, so that the position of its vibration-plane can be fixed. The analyzing prism is placed above the eye-picce in a support, $s$, which may be removed at
pleasure; the edge of this is graduated and a fixed mark on the plate, $f$, makes it possible to set the vibration-plane in any desired position. When both prisms are set at the zero mark, their vibration-planes are crossed (土); when either is turned $90^{\circ}$, the planes are parallel $(\|)$. The stage is made to rotate about the vertical axis, but otherwise is fixed ; its edge is graduated, so that the angle through which it is turned can be measured to $\frac{1}{2}^{\circ}$. Three adjustment screws, of which one is shown at $n, n$, make it possible to bring the axis of the object glass in coincidence with axis of rotation of the stage (see further the detailed drawing at the side).

This instrument is especially applicable to the study of the form and optical properties of minerals as they are found in thin sections of rocks (on the method of preparing see p. 159), although it can also be used with small independent crystals and crystalline sections or fragments. The more important points to which the attention is to be directed, more particularly in the case of minerals in sections of rocks, are : (1) crystalline form, as shown in the outline; (2) direction of cleavage lines; (3) index of refraction; (4) light absorption in different directions, i. e., dichroism or pleochroism ; (5) the isotrope or anisotrope character, and if the latter, the direction of the planes of light-vibration-this will generally decide the question as to the crystalline system ; (6) position of the axial plane and nature of the axial interference figures when they can be obscrved, and the positive or negative character of the double refraction ; (\%) inclosures, solid, liquid or gaseous.
In regard to these several points a few general remarks may be made.*
(1) Crystalline Form.-In most rocks well defined crystals are rather the exception than the rule. It will be consequently only in occasional sections (e. g. more commonly in volcanic rocks) that a clear crystalline outline is ooserved. The form of this outline will defend upon the direction in which the section is cut, and will vary as it varies; this fact will explain why in a given rock section so many widely different forms of a given mineral are observed ; this irregularity is increased by the fact that the crystals may be more or less distorted. For the recognition of the form, consequently, considerable familiarity with the various outlines likely to occur in the case of a given species is very desirable.

The angles between any two crystalline directions is obtained by first bringing one of them in coincidence with a spider line in the eye-piece, the adjustment at $N$ having been previously made, and then noting the angle through which the crystal, i. e., the stage, must be rotated to bring the other direction in coincidence with the same spider line.
(2) C'leavage.-The process of grinding involved in the making of a thin section tends to develop the cleavage lines. Here are to be noted, (1) the direction of cleavage (measured as above), depending on the direction in which the section is cut; and (2) the character of the cleavage. For example, a basal section of a crystal of amphibole shows the cleavage lines parallel to the prism ( $124_{\frac{1}{2}^{\circ}}$ ); a vertical section shows one set of vertical and parallel

[^24]cleavage lines. On the other hand, a basal section of a crystal of pyroxene shows the prismatic cleavage, here less perfect than in the amphibole, and at an angle of $87^{\circ}$ and $93^{\circ}$; a vertical section again shows only one set. Also a basal section of mica shows no cleavage lines, but a vertical section shows a series of very fine parallel lines corresponding to the highly perfect basal cleavage.
(3) The index of refraction is obtained by the method of the Duke de Chaulnes, as developed by Sorby (see p. 1i8).
(4) Pleochroism.-To examine the pleochroism of a mineral section, the lower prism is inserted and set at $0^{\circ}$, so that its vibration-plane coincides with the direction $0^{\circ}$ to $180^{\circ}$ on the stage. If now the section be placed on the stage and the latter rotated, the absorption of the light vibrating in the same plane with the prism can be observed. For example, a vertical section of biotite is dark when the direction of the cleavage lines is $\|$ with the above named line ( $0^{\circ}$ to $180^{\circ}$ of stage), for the light which it transmits has vibrations in this plane only, and these are strongly absorbed ; on the contrary, when the stage is rotated $90^{\circ}$ the section becomes light, because the light vibrating \|t to this direction, is but slightly absorbed; on the other hand, a basal section shows no difference of light absorption.
(5) Isotrope or Anisotrope, etc.-Supposing the prisms in position and placed with their vi-bration-planes perpendicular, a section of an amorphous substance, as glass, will remain dark in all positions as it is rotated upon the stage, for it has sensibly the same light-elasticity in all directions, since no one direction has any advantage over another.

A section of an isometric mineral will also remain dark as it is revolved between the crossed prisms. A section of a tetragonal or hexagonal crystal parallel to the base will also remain unchanged between crossed prisms; a vertical section, or one inclined to the base, will be dark only when the directions of the spider lines coincide with the vertical and transverse directions ; in other words, the extinction directions are $\|$ and $\perp$ to the prism. A section of an orthorhombic crystal will have its directions of extinction coincident with the crystallographic axes. A section of a monoclinic crystal cut parallel to any direction in the orthodiagonal zone will have its extinction directions parallel to the clinodiagonal axis and perpendicular ; that is, if prismatic in habit. II and $\perp$ to the prism, hence in this position it cann th be distinguished from an orthorbombic crystal. On the other hand. in the case of a section cut in any other plane, the position of the extinction directions will depend upon the ind, vidual crystal. For the exact determination of these directions with reference to any crystallographic lines present, the method of the stauroscope must be employed. For minute sections a quartz plate ( 1 vertical axis) is sometimes inserted ( $Z Z$ at $t t$ in f. 412 K ); this gives for a proper position of the upper prism a field of uniform delicate color (say violet). A section of an anisotrope mineral placed on the stage will have the same color only when its extinction directions are $\|$ and $\perp$ to the vibration plane of the lower prism ( $r r$, in f. 412 K ). A special eye-piece (see f. 412 K ) provided with a Calderon plate is also sometimes employed.
(6) If the eye-picce is removed, and at the same time suitable lenses added, two at $T$ (f. 412 K ) and one above, strongly converging light is obtained. In many cases whn the section is cut in the proper direction, the axial interference figures can be seen as distinctly as in the ordinary polariscope. A $\frac{1}{4}$-undulation mica plate makes it possible in such cases to determine the + or - character of the double refraction. On the use of microscope for the observation of the optic axes, see v. Lasaulx, J. Min., 1878, 377 , and Z. Kryst., ii., 256 ; Bertrand, Bull. Soc. Min., 1878, 27 ; Klein, Nachr. Ges. Wiss. Göttingen, 18i8, 461 ; Laspeyres, Z. Kryst., iv., 460.
(7) For a description of the various inclosures often observed in sections of minerals, and the method of studying them, reference must be made to the works referred to above.

When it is desired to observe the effect of increased temperature on the mineral sections or their enclosures (e.g. liquid $\mathrm{CO}_{2}$ ) the air bath (f. 412L) heated by the lamp, $L$, and provided with a delicate thermometer, is employed. This fits into the stage at $T$, and the section is placed above at ss.

Microscope of Bertrand.-Bertrand (Bull. Soc. Min., iv., 9\%-100, 1880) has devised a form of microscope especially adapted for mineralogical work, and allowing of the determination of the form and optical properties of minerals in crystals or sections so small that they cannot be employed in the ordinary polariscopes. The tube carrying the eye-piece and objective has the ordinary coarse and fine adjustments; the former is accomplished by a rack and pinion movement, and is measured by a scale and vernier; the latter is made by a serew with a graduated head situated similarly to that in the Rosenbusch microscope. An opening in the tube above the objective allows of
the introduction of a little slide carrying a small lens, whose vertical position can be adjusted by an appropriate rack and pinion turned by a screw head ; this auxiliary lens may either magnify the interierence figures of the crystal section or else the section itself, when the position of the former is properly adjusted. The objective can be centered by horizontal screws, and immediately above it a quartz wedge, or quarter-undulation plate of mica, can be introduced for the determination of the character of the double refraction. The stage has two movements in directions at right angles to each other, for each of which a special scale with a vernier is supplied ; also, the stage rotates in a horizontal plane, and is supplied with a graduation to allow of the measurement of the angle of rotation. The lower polarizing prism is supplied with several lenses for producing strongly converging light, and by a screw can be moved in a vertical direction. In addition, a small goniometer with oil bath is provided, which can be placed upon the stage, and which allows of the measurement of the optic axial angle of the section under examination. The special advantages of this instrument, as shown by the observations of the inventor with it, as also those of Des Cloizeaux, are that it allows of all the necessary optical determinations even in crystals or crystal sections which are extremely minute.

## On the Cause of the so-called Optical Anomalies of Crystals.

[The following paragraphs contain a brief statement of the results of some of the more important of recent investigations bearing upon the subject of the "Optical Anomalies" of crystals. It will be seen that the main point at issue is as to the true explanation of the phenomena of double-refraction, observed in many crystallized minerals of apparent isometric form (as garnet, fluorite, boracite, analcite, ete.), and analogous variations from the theoretical optical character in crystals apparently tetragonal, hexagonal, etc. (as vesuvianite, zircon, corundum, beryl, etc.). Are these "optical anomalies" a proof that the apparent symmetry of the observed form is only pseudo-symmetry, being due to the complex twinning of parts of lower grade of symmetry than that which the crystal as a whole simulates? In other words, do the optical properties actually belong to the inherent molecular structure of the parts of the crystal ? Or, does the geometrical form of the whole really represent the true symmetry of the crystal, and are these phenomena (of double-refraction in isometric crystals, for example) due to secondary causes, such as internal tension produced during the growth of the crystal, and so on ?
In regard to this subject, it may be remarked that it is beyond question, on the one hand, that pseudo-symmetry is to some extent a law of nature, for the crystals of many mincrals of unquestioned orthorhombic character simulate hexagonal forms (e. g., aragonite) ; on the other hand, it is equally certain that the phenomena of double-refraction may be produced in colloid or crystaline isotrope media by a state of tension, and similarly that uniaxial crystals may be made biaxial by pressure, and so on. Which of these two explanations is to be applied in the large number of cases now under discussion cannot be regarded as settled, although the writer inclines to the opinion that the second explanation, more fully detailed later, will be found to hold true in the case of the majority. This does not seem, however, to be the place nor the time for a full review of the testimony which has been accumulated on both sides of the question.]

There are a considerable number of minerals, the crystals of which exhibit optical phenomena which are not in accordance with the apparent symmetry of the crystalline form. Cases of this kind were observed by Brewster ( 1815 and later), and investigated by him with a remarkable acuteness considering the imperfect instruments then available. For example, alum, analcite, boracite, diamond, fluorite, halite were shown by Brewster to exert an effect on polarized light not in accordance with their apparent isometric form. With the improved methods and means of investigation at the disposal of mineralogists in recent times, the list of minerals whose crystals exhibit "optical anomalies" has been very largely increased.

In explanation of these anomalies, various hypotheses have been advanced. Brewster explained them in the case of diamond as due to local tension connected with solid or gaseous inclosures. In 1841 Biot published his memoir on lamellar polarization (C. R. xii., 967 ; xiii., 155, 391, 839), and explained the optical characters of the minerals named above, as also the tetragonal apophyllite, as due to that cause. The idea advanced by him was that the crystal was made up of thin lamellæ, which exerted on transmitted light an effect analogous to that of a bundle of parallel glass plates. Volger (1854-5) attempted to show that in the case of boracite the anomalous optical properties were due to the presence of a doubly-refracting anisotrope mineral, parisite, derived from alteration ; much later (1868) this view was accepted by Des Cloizeaux. Marbach (Pogg. Ann., xciv., 412, 1855) discussed the question more broadly, and concluded that the phenomena observed were due to the presence in the normal substance of abnormal anisotrope portions, which last owed their existence to a tension produced at the time the crystal was formed. It was further shown by von Reusch (ib. cxxxii., 618,1867 ) that the hypothesis of Biot was not sufficient to explain the observed facts in the case of alum. He also took up the view of Marbach, and following out much the same idea as that of Marbach, reached the conclusion that the anisotrope characters of isometric crystals were due to the condition of internal tension existing within the crystal. As bearing upon the question he proved by experiment that by suitable pressure, in the case for example of alum crystals, the double-refraction could be removed. The influence of pressure in causing double refraction was early investigated by F. E. Neumann (Pogg. Ann., liv., 449, 1841), and by Pfaff (ib., cvii., 333 ; cviii., $578,1859)$. The subject has also been discussed by Hirschwald (Min. Mitth., 1875, 227).

More recently the idea of internal molecular tension as a cause of anomalous optical characters has been developed by Klocke, Jannettaz, Klein, Ben Saude and others, as more particularly described later.

In $18 \% 6$ Mallard published his most important memoir (Ann. Min., VII., x., 60-196) upon this subject, in which he not only gave a very large number of new facts of a similar nature, but also advanced a new explanation which has been warmly accepted by some mineralogists. He regards all the indications of double-refraction observed in apparent isometric crystals, and analogous variations from the normal character in crystals of other systems, as proof that the form is only apparently isometric, tetragonal, and so on (pseudo-isometric, pseudo-tetragonal, etc.), the union of several individual crystals giving rise to an external form of a higher grade of symmetry than that which they themselves possess. On his view, an apparent isometric cube may, in fact, be a combination of six uniaxial crystals (counting two parallel as one, in fact only three independent), each having the form of a square pyramid, united so that their bases form the sides of the cube, and their vertices are combined at the centre. Again, an apparent regular octahedron may be made up of eight uniaxial triangular pyramids, similarly placed ; a dodecahedron of twelve rhombic pyramids (boracite), or perhaps of forty-eight triclinic triangular pyramids, the bases of four combining to form a rhombic face. In most of these cases the optic axis coincides with the axis of the pyramid.
Mallard thus includes among pseudo-isometric species: alum, analcite, boracite, fluorite, garnet, senarmontite; among pseudo-tetragonal species: apophyllite, mellite, octahedrite, rutile, vesuvianite, zircon ; among pseudo-
hexagonal species: apatite, beryl, corundum, penninite, ripidolite, tourmaline ; pseudo-orthorhombic species: harmotome, topaz; pseudo-monoclinic: orthoclase.

Many observations similar to those of Mallard have been made by Bertrand (in Bull. Soc. Min., 18\%8-1882), who applies the same method of explanation to them. For explanation, Bertrand has described crystals of garnet which were biaxial, with an angle of about $90^{\circ}$; a hexoctahedron being made up, in his view, of forty-eight triangular pyramids, four to each pseudo-rhombic pyramid. Each pyramid is biaxial, with the acute negative bisectrix nearly normal to the base, and the axial plane coincides with the direction of the longer diameter of the rhombic face. Further, apparent tetrahedral crystals of romeite are regarded as formed of four rhombohedrons of $120^{\circ}$, placed with their vertices at a common point. Also in the case of romeite the octahedrons are, in his view, formed by the grouping of cight rhombohedral crystals of $90^{\circ}$ about a central point. The above will serve as illustrations. Bertrand has extended his observations over a considerable number of species, and the explanation given by Mallard of the optical phenomena just described is strongly supported by him, as against the Mar-bach-Reusch theory of molecular tension, more minutely described below. Bertrand urges (Bull. Soc. Min., r., 3, 188\%) that a true doubly-refracting crystal, whether simple or a complex twin, can always be distinguished from a crystal normally isotrope, but modified throngh internal tension or any other cause. The difference, he states, is to be seen in parallel polarized light, where the former will show a distinctness and uniformity of character which does not belong to the latter ; still more clearly in converging light, where the truly doubly-refracting crystal shows throughout the same characters, each fragment into which the section may be broken giving the identical uniaxial or biaxial figures with the whole ; on the other hand, this cannot be true of the different parts of a crystal made doubly-refracting through some cause, as contraction, and so on. As illustrations of these facts, he appeals to boracite, garnet, pharmacosiderite, etc., stating that, as the result of his observations, they fall into the former class. He speaks further of octahedrons of boracite formed of twelve biaxial crystals, and of romeite formed of eight uniaxial crystals, as showing that the internal structure is independent of the external form; as bearing further upon this point, it is stated that the imperfect crystals of the garnet rock of Jordansmühl show the same twinning of biaxial individuals as do isolated crystals of garnet, whose external form is complete. But reference must be made to the observations alluded to beyond, which do not entirely support the conclusions of Bertrand.

This subject has been discussed by Grattarola, who includes calcite, quartz, nephelite, barite, etc., in the list of species which have an apparent symmetry higher than that which really belongs to them ; his conclusions, however, are not based upon observations (Dell' unità cristallonomica in Mineralogia, Florence, 18\%\%).

In many other cases, besides those mentioned above, observers have, on the basis of variation in angles, or of optical characters, reached the conclusion that the species in question really belongs to a system of lower symmetry than that to which it has been ordinarily referred. For example, see Des Cloizeaux on microcline and milarite ; Rumpf on apophyllite (Min. Petr. Mitth., ii., 369) ; Becke on chabazite (ib., ii., 391), and hessite (ib., iii., 301); Schrauf on brookite (Ber. Ak. Wien, lxxiv., 535 and Z. Kryst., i., 274) and
other species ; Brezina on autunite (Z. Kryst., iii., 273 ); Tschermak on the micas (Z. Kryst., ii., 14) and corundum (Min. Petr. Mitth., ii., 362) ; and many other cases. These last named observations, however, do not generally admit of being explained on the hypothesis of Mallard. In many of them the conclusions reached are beyond doubt correct, in others the question must be regarded as still undecided.

Tschermak proposes the term mimetic for those forms (" mimetische Formen "), which imitate a higher grade of symmetry by the grouping (twinning) of individuals of a lower grade of symmetry, as for example, aragonite ; also, chabazite, which, according to Becke, is apparently rhombohedral, but, in fact, formed by a complex twinning of triclinic individuals (this conclusion, however, is not universally accepted). He also uses the term pseudo-symmetry to describe the phenomena in general (ZS. G. Ges., xxxi., 657,1879 , and Lehrb. Min., p. 89 et seq., 1881).

The explanation of the optical phenomena referred to above, which was presented by Marbach and later developed by Reusch, has been recently still further elaborated by Klocke (J. Min., 1880, i., 53, 158), Klein, Jannettaz, Ben Saude. Klocke's first observations were made upon artificial crystals of alum. He found that each crystal (contrary to earlier statements) showed doubly refracting properties as strongly normal to an octahedral plane as in other directions. A section parallel to this plane was divided into s.y sectors by radial lines passing from the angles to the centre ; the directions ot extinction in each sector being $\|$ (parallel) and $\perp$ (perpendicular) toits outer edge, these directions consequently coinciding for each pair of opposite sectors. These sectors behaved as if made up of bands in a state of tension parallel to their longer direction ; a similar result was obtained by subjecting a six-sided octahedral and isotrope alum section to pressure perpendicular to two of its edges. He found further that all the sections of the same crystal, independent of the crystallographic orientation, were alike as regards the direction of the tension, and that all crystals made at the same time, that is, under the same conditions, yielded identical results; but this was not true of crystals made at different times. Further it was found that the distortion peculiar to the crystal exerted an essential effect upon the number and arrangement of the optical sectors, and that the position which the crystal occupied in the vessel during its formation was also an important factor.

Later the same author (J. Min., 1881, ii., 249) has extended his observations to some of the species exhibiting pseudo-symmetry. He shows, among other results, that pressure exerted normal to the vertical axis of a section of a tetragonal or hexagonal crystal which has been cut $\perp \boldsymbol{c}$ (vert.), changes the uniaxial interference figure into a biaxial, and with substances optically positive, the plane of the optic axes is parallel, and with negative substances normal, to the direction of pressure. This was observed on sections of vesuvianite and apophyllite which exhibited uniaxial portions. Many sections are divided into four optical fields (biaxial) with the axial plane-perpendicular to the edge. The behavior of each field in a section of apophyllite consequently is (optically + , sse above) as if in a state of tension parallel to the adjacent com-bination-edge with the prism; but with vesuvianite (optically -) the direction of tension is perpendicular. This explanation is supported by the fact that pressure exerted in the proper direction serves, in accordance with the above principles, respectively to increase or diminish the axial angle. The author also succeeded in obtaining axial interference figures visible in converging polarized light in gelatine sections when under pressure; the same phenomenon in parallel light had been earlier observed.

On the observations of Jannettaz, showing the effect of internal tension in causing double-refraction, see Bull. Soc. Min., ii., 124 ; ii., 191 ; iii, 20.

The results of the observations of Klein (J. Min., 1880, ii., 209 ; 1881, i., 239) on boracite have an important bearing upon this subject. As stated above, it is included by Mallard among the pseudo-isometric species. Basing his results more especially upon the examination of crystals of dodecahedral habit, Mallard concluded that the apparent simple form is made up of twelve rhombic pyramids whose basal planes form the twelve faces of the dodecahedron. Baumhauer, on the basis of results of etching experiments, more particularly on crystals of octahedral habit, concluded that the species was orthorhombic, the apparent simple form being made up of six individuals whose bases would coincide with the cubic planes (p. 187). The observations of Klein show that the structure of the crystals of different habits vary-some agreeing with the scheme of Mallard-some with that of Baumhauer ; he shows, however, very conclusively (as it seems to the writer) that this apparently complicated structure is probably due to internal tension produced during the growth of the crystals. Crystallographically there is no variation in angle from the requirements of the isometric system to be observed. In regard to the optical characters, he shows that the interior optical structure does not correspond to the exterior planes; that the etching figures do not correspond to the optical limits; that a change of temperature alters the relative position of the optical fields without influencing the form of the etching figures; that the differently orientired optical portions lose their sharp limits, they change their position relatively, some disappearing in part or whole, and others appearing.* Klein has also made a series of optical studies on garnet (Nachr. Ges. Wiss. Güttingen, June 28, 1882), and after a review of the whole subject decides in favor of the true isometric character of the species; the double-refraction phenomena observed being due to secondary causes.

Ben Saude (J. Min., 1882, i., 41) has investigated analcite, and arrived at the conclusion that with it also the abnormal optical characters are to be explained by internal molecular tension. He shows that the crystals are formed of different optical parts, in combinations of 30 with the cube and trapezohedron together, and 24 for the trapezohedron alone, the form of which changes as the outer surfaces of the crystals change. The structure can be explained in this way, as made up of pyramids going from each plane to the middle of the crystal having the plane as its base, with as many sides as there are edges to the plane; as the outer form changes the optical structure changes correspondingly ; every edge corresponds to an optical boundary, and every plane to an optical field. All these double-refraction phenomena are explained as due to secondary causes. Moreover, the author has proved that gelatine cast into the form of the natural crystals has on solidifying an analo-

[^25]gous optical structure, showing the same sections, the same directions of lightextinction, and under favoring conditions the same position of the optic axes. Ben Saude has also examined perofskite (Gekrönte Preisschrift der Universität Göttingen, 1882) from the same standpoint, with reference to the etchingfigures and optical phenomena. He concludes that it is to be referred to the isometric system, and that the double refraction is to be explained as caused by changes in the original position of equilibrium produced in the growth of the crystals. This conclusion, however, is at variance with the results of the observations of others.

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## PARTII.

## UHEMICAL MINERALOGY.

Minerals are either the uncombined elements in a native state, or com pounds of these elements formed in accordance with chemical laws. It is the object of Chemical Mineralogy to determine the chemical composition of each species; to show the chemical relations of different species to eadeh other where such exist ; and also to explain the methods of distinguishing different minerals by chemical means. It thus embraces the most important part of Determinative Mineralogy.

## Chemical Constitution of Minerals.

In order to understand the chemical constitution of minerals, some knowledge of the fundamental principles of Chemical Philosophy is required; and these are here briefly recapitulated.

Chemical elements.-Chemistry recognizes sixty-four substances which cannot be decomposed, or divided into others, by any processes at present known; these substances are called the chemical elements. Of these oxygen, hydrogen, and nitrogen are fixed gases; chlorine and floorine are generally gases, but may be condensed to the liquid state; bromine is a volatile liquid; and the rest, under ordinary conditions, quicksilver excepted, are solids. Of these last carbon, phosphorus, arsenic, sulphur, boron, (tellurium), selenium, iodine, silicon, generally rank as non-metallic elements, and the others as metallic.*

Molecules; Atoms.-By a molecule is understood the smallest portion of a substance which possesses all the properties of the matter itself; it is the smallest division intn which the substance can be divided without loss or change of character. The molecule of water is the smallest conceivable particle which can exist alone, and which has all the properties of water. An atom is the smallest mass of each element which enters into combination with others to form the molecule. Thus two chemical units, or atoms, of hydrogen unite with one atom of oxygen to form the physical unit, or molecule, of water.

Atomic weights.-The relative weights of the chemical units, or atoms, of the different elements are their atomic weights. For the sake of uni-

[^26]formity the atom of hydrogen, the lightest of all the elements, has been adopted as the standard or unit. The absolute weight of the atoms cannot be determined ; but their relative weight can in many cases be fixed beyond question. When the elements are gases, or form gaseous compounds, the atomic weights are determined directly. Thus in hydrochloric acid gas there are equal volumes of hydrogen and chlorine, or, chemically expressed, one atom of hydrogen combines with one atom of chlorine ; by analysis it is found that in 100 parts there are 2.74 by weight of hydrogen, and 97.26 of chlorine ; hence if hydrogen be taken as the unit, the atomic weight of chlorine is $35 \cdot 5$, since $2 \cdot 94: 97 \cdot 26=1: 35 \cdot 5$.

Where the elements, or their compounds, are not gases, the atomic weights are determined more or less indirectly, and are sometimes not entirely free from doubt. The analysis of rock-salt gives us, in 100 parts, $60 \cdot 68$ parts of chlorine, and 39.32 parts of sodium ; now if, as is believed, the number of units of each element involved is the same, or in other words, if the molecule consists of one atom each of chlorine and sodium, then the atomic weights will be as $60 \cdot 68: 39 \cdot 32$; or $35 \cdot 5: 23$, since that of chlorine $=35 \cdot 5$. Hence the atomic weight of sodium is 23 , when referred, like chlorine, to that of hydrogen as the unit. There is an assumption in such cases as to the number of units of each element involved which may introduce doubt, so that other methods are applied which need not be here detailed.

The following table gives the atomic weights of the elements. The symbols nsed to represent an atom of each element are shown in the table; in most cases they are the initial letter or letters of the Latin name. When more than one atom is involved in the formation of a compound, it is indicated by a small index number placed below, to the right: as $\mathrm{Sb}_{2} \mathrm{O}_{3}$, which signifies 2 of antimony to 3 of oxygen. The quantity by weight of any element entering into a compound is always expressed either by the atomic weight or some multiple of it; hence the atomic weights are strictly the combining weights of the different elements.

Atomit Weights.

| Aluminum | Al | $27 \cdot 3$ | Cobalt | Co | 59 |
| :---: | :---: | :---: | :---: | :---: | :---: |
| Antimony | Sb | 122 | Columbium (Niobium) | $\mathrm{Cb}(\mathrm{Nb})$ | 94 |
| Arsenic | As | 75 | Copper | Cu | 63.4 |
| Barium | Ba | 137 | Didymium* | D | 96.5 |
| Bismuth | Bi | 208 | Erbium | E | $112 \cdot 6$ |
| Boron | B | 11 | Fluoriue | F | 19 |
| Bromine | Br | 80 | Gallium | Ga | $69 \cdot 8$ |
| Cadmium | Cd | 112 | Glacinum (Beryllium) | G (Be) | 9 |
| Cæsium | Cs | 183 | Gold | Au | 196 |
| Calcium | Ca | 40 | Hydrogen | H | 1 |
| Carbon | C | 12 | Indium | In | $113 \cdot 4$ |
| Cerium* | Ce | 92 | Iodine | I | 127 |
| Chlorine | Cl | 35.5 | Iridium | Ir | 198 |
| Chromium | Cr | 52 | Iron | Fe | 56 |

[^27]| Lanthanum | La | 92.5 | Selenium | Se | 79 |
| :---: | :---: | :---: | :---: | :---: | :---: |
| Lead | Pb | 207 | Silver | Ag | 108 |
| Lithium | Li | 7 | Silicon | Si | 28 |
| Magnesium | Mg | 24 | Sodium | Na | 23 |
| Manganese | Mn | 55 | Strontium | Sr | 88 |
| Mercury | Hg | 200 | Sulphur | S | 32 |
| Molybdenum | Mo | 96 | Tantalum | Ta | 182 |
| Nickel | Ni | 59 | Tellurium | Te | 128 |
| Nitrogen | N | 14 | Thallium | Tl | 204 |
| Osmium | Os | 200 | Thorium | Th | 231 |
| Oxygen | 0 | 16 | Tin | Sn | 118 |
| Palladium | Pd | 106 | Titanium | Ti | 50 |
| Phosphorus | P | 31 | Tungsten | W | 184 |
| Platinum | Pt | 198 | Uranium | U | 240 |
| Potassium | K | 39 | Vanadium | V | 51.4 |
| IRhodium | Ro | 104 | Yttrium | Y | $61 \cdot 7$ |
| Rubidium | Rb | $85 \cdot 4$ | Zinc | Zn | 65 |
| Ruthenium | Ru | 104 | Zirconium | Zr | 90 |

Atomicity ; Quantivalence.-The combining power of each element is measured by the number of hydrogen atoms with which it combines in forming a chemical compound. In hydrochlorice acid ( HCl ), one atom of hydrogen combines with one of chlorine; in water $\left(\mathrm{H}_{2} \mathrm{O}\right)$, two atoms of hydrogen combine with one of oxygen ; in ammonia $\left(\mathrm{H}_{3} \mathrm{~N}\right)$, three atoms of hydrogen combine with one of nitrogen ; and in marsh gas $\left(\mathrm{H}_{4} \mathrm{C}\right)$, four atoms of hydrogen are required to enter into combination with one carbon atom.

By the examination of compounds of all the elements we are able to fix the combining power, or quantivalence, of each, expressed in hydrogen units. All those elements which combine with one atom of hydrogen, or an element which (like chlorine) has the same quantivalence, are called monads ; those which require two of hydrogen, or two other monad atoms, in forming the compound, are called dyads; those uniting with three atoms of hydrogen are called triads ; and similarly tetrads, pentads, hexads, and heptads.

The adjective terms univalent, bivalent, trivalent, quadrivalent, etc., are also employed with similar meaning. Atoms having the same degree of quantivalence are said to be equivalent; this is true of Na and $\mathfrak{K}$, both monads, and they may replace each other in similar compounds; but it requires two sodium atoms to be equivalent to one calcium atom, since the latter is a dyad.*

The degree of quantivalence may vary for many of the elements in different compounds; for example, in FeO or FeS , iron ( Fe ) is bivalent, since it satisfies or is combined with simply a dyad; in $\mathrm{FeS}_{2}$, it is quadrivalent, since it is united to two atoms of a dyad; and, similarly, in $\left[\mathrm{Fe}_{2}\right] \mathrm{O}_{3}$ it is sexivalent (for the double atom).

Perissads; Artiads. Those elements whose atoms have an odd quanti. valence (I, III, V, or VII), are called perissads ; those whose quantivalence is even (II, IV, VI) are called artiads. These terms, perissad and artiad, are derived from $\pi \epsilon \rho \iota \sigma \sigma o s$ and áp $\rho \iota o s$, the words for odd and even in ancient arithmetic. The following table gives the division of the elements into these two classes, and shows, also, the quantivalence of each elo ment :

## Perissads.

## Monads:-

Hydrogen.
Fluorine.
Chlorine, I, III, V, VII. Bromine, I, III, V, VII. Iodine, I, III, V, VII.

Lithium.
Sodium, I, III.
Potassium, I, IUI, V.
Rubidium.
Cæsium.
$\begin{array}{ll}\text { Silver, } & \text { I, III. } \\ \text { Thallium, } & \text { I, III. }\end{array}$
Triads:-
Nitrogen, I, III, V. Phosphorus. I, III, V.
Arsenic, I, III, V.
Antimony, III, V.
Bismuth, III, V.
Boron.
Gold, I, III.
Pentads:-
Columbium.
Tantalum.
Vanadium, III, V.

## Artiads.

Dyads:-
Oxygen.
Sulphur, II, IV, VI.
Selenium, II, IV, VI.
Tellurium, II, IV, VI.
Calcium, II, IV.
Strontium, II, IV.
Barium, II, IV.
Magnesium.
Zinc.
Cadmium.
Glucinum.
Yttrium.
Cerium.
Lanthanum.
Didymium.
Erbium.
Mercury $\left[\mathrm{Hg}_{2}{ }^{\text {II }}\right.$, II.
Copper $\left[\mathrm{Cu}_{2}\right]^{\mathrm{H}}, \mathrm{II}$.

Tetrads :-
Carbon, II, IV.
Silicon.
Titanium, II, IV.
Tin, II, IV.
Thorium, Zirconium.

| Platinum, | II, IV. |
| :--- | ---: |
| Palladium, | II, IV. |
| Lead, | II, IV. |
| Indium. |  |

Hexads :-
Molybdenam, II, IV, VI. Tungsten, IV, VI.

| Ruthenium, | II, IV, VI. |
| :--- | :--- |
| Rhodium, | II, IV, VI. |
| Iridium, | II, IV, VI. |
| Osmium, | II, IV, VI. |
| Aluminum, | IV, [Al ${ }^{\text {IVI }}$ II. |
| Chromium, | II, IV, VI. |
| Manganese, | II, IV, VI. |
| Iron, | II, IV, VI. |
| Cobalt, | II, IV. |
| Nickel, | II. IV. |
| Uranium, | II, IV. |

The general divisions of chemical compounds now accepted are as follows.

1. Binaries, where the atoms are directly united. Examples are given by the compounds of a positive (basic) element with oxygen ( $\mathrm{Na}_{2} \mathrm{O}, \mathrm{CaO}$, $\mathrm{CO}_{2}$ ), called oxides ; those with sulphur, chlorine, bromine, iodine, etc., called sulphides, chlorides, etc. Binary compounds of a negative element with hydrogen (as $\mathrm{HCl}, \mathrm{HBr}$ ) form acids.
2. Lernaries, where the atoms are united by means of a third atom, as oxygen, sulphur, etc., as $\mathrm{CaSO}_{4}, \mathrm{Mg}_{2} \mathrm{SiO}_{4}$, etc.

Among minerals there are three classes of compounds ! (1) The Native Elements; (2) Binary compounds, including the sulphides, oxides, chlorides, iodides, fluorides ; (3) Ternary compounds, including sulph-arsenites, etc., hydrates (hydrated oxides), silicates, mostly salts of the acids $\mathrm{H}_{4} \mathrm{SiO}_{4}$ and $\mathrm{H}_{2} \mathrm{SiO}_{3}$, tantalates, columbates, phosphates, arsenates, sulphates, chromates, carbonates, etc. The full enumeration of these compounds, with their general chomical formulas, are given in the synopsis which precedes the Descriptive Mineralogy.

The position of water in the composition of minerals.-Many minerals lose water, especially upon the application of heat. With some of these it is given off upon mere exposure to dry air at ordinary temperature, and such erystals are said to effloresce; others lose water when they are placed in a dessceator over sulphuric acid, or when they are subjected to a slightly
elevated temperature; with others, again, a greater heat is required; and with a few silicates water is yielded only upon long continued heating at a very high temperature. It is evidently possible that either, (1) the mineral contains water as such, or (2) the water is formed by the process of decomposition caused by the application of heat. In the cases first mentioned, where water is readily given off, it is believed that the water actually exists as such in the compound. It is found that many salts take up water when they crystallize, and in some cases the amom of water depends upon the temperature at which the salt is formed; this water is called water of crystallization. For example: manganous sulphate has three definite amomen of this water of crystallization, according to the temperature at which it has been formed. When crystallized below $7^{\circ}$, its composition is $\mathrm{MnSO}_{4}+7 \mathrm{H}_{2} \mathrm{O}$; between $7^{\circ}$ and $20^{\circ}, \mathrm{MnSO}_{4}+5 \mathrm{H}_{2} \mathrm{O}$; and between $20^{\circ}$ and $30^{\circ}, \mathrm{MnSO}_{4}+4 \mathrm{H}_{2} \mathrm{O}$.

In those cases where a very high temperature is required to make a loss of water, it is quite certain the water has no place as such in the original constitution, but, on the contrary, that the mincral contains basic hydrogen, replacing the other basic elements. In some cases, where part of the water is yielded at a low and the rest at a very high temperature, this shows that a difference exists in regard to the part which the water plays in the two cases ; for example, crystallized sodium phosphate yields readily 24 equivalents of water, while the remaining 1 molecnle is given off only at a temperature between $300^{\circ}$ and $400^{\circ}$; from this it is concluded that in the latter case the elements forming the water exist actually in the salt, and that its composition is :

$$
\mathrm{H}_{2} \mathrm{Na}_{4} \mathrm{P}_{2} \mathrm{O}_{8}+24 \mathrm{aq} .
$$

The part played by the water in the silicates is in most cases still undecided, though in many species the hydrogen is undoubtedly basic. The latter is doubtless true of many of the so-called hydrous silicates. The views commonly held in regard to them will be gathered from the descriptive part of this work.

Chemical formulas for minerals.-A chemical formula expresses the relative amounts of the different elements present in the compound, in terms of their atomic weights-or, in other words, more strictly the number of atoms of each element in a given molecule with or without the expression of their probable grouping.

Empirical formulas simply state in the briefest form the result of the analysis, giving the number of atoms of each element present without any theoretica' 'onsiderations. For example, the empirical formula of epidote is $\mathrm{Si}_{6} \mathrm{Al}_{3} \mathrm{Ca}_{4} \mathrm{H}_{2} \mathrm{O}_{26}$.

The object of the rational formulas is to express not only the number of atoms of each element present, but also their probable method of grouping, and relation to each other, in the molecule. These are called typical formulas when the attempt is made to arrange the atoms in accordance with the type of water, or some other type.

In the rational formulas of the old chemistry the oxygen (or sulphur) was apportioned to the several elements, according to their combining power, and the basic and acid oxides, or sulphides, thus obtained were written cousecutively. For example, the formula of wollastonite (calcium sili-
cate), according to the old dualistic method, was written $\mathrm{CaO}, \mathrm{SiO}_{2}$, and of anhydrite (calcium sulphate), $\mathrm{CaO}, \mathrm{SO}_{3}$. The principles of the new chemistry have set aside these rational formulas; but as others consistent with the new principles now adopted have not in all cases been accepted, it is customary to give the formulas of minerals empirically. For those above the empirical formulas are $\mathrm{CaSiO}_{3}$ and $\mathrm{CaSO}_{4}$.

Relation between the old and new systems.-The points of difference between the old and new chemistry have already been hinted at. The principal changes which have been introduced by the latter are: (1) The doubling of all the atomic weights, except those of the monad elements, and also of bismuth, arsenic, antimony, nitrogen, phosphorus, and boron, whose oxides are now written $\mathrm{Bi}_{2} \mathrm{O}_{3}$, instead of $\mathrm{BiO}_{3}$, etc. Corresponding to this change, binary compounds involving the monad elements are written: $\mathrm{H}_{2} \mathrm{O}$ instead of $\mathrm{HO}, \mathrm{Na}_{2} \mathrm{O}$ for $\mathrm{NaO}, \mathrm{Na}_{2} \mathrm{~S}$, etc., also $\mathrm{CaCl}_{2}$ instead CaCl , $\mathrm{SiF}_{4}$ instead of $\mathrm{SiF}_{2}$, and so on. (2) The method of viewing the composition of ternary compounds-these being now regarded not as compounds of an oxide and a so-called acid, but as compounds for the most part of the several elements concerned, and hence a metal in a compound is believed to be replaced by another metal, not one oxide by another. Hence we say calcium carbonate, or carbonate of calcium instead of carbonate of lime, and write the formula $\mathrm{CaCO}_{3}$, not $\mathrm{CaO}, \mathrm{CO}_{2}$; and so in the other cases.

Replacing power of the different elements.-It has been mentioned that the replacing power of the elements is in proportion to their combining power, that is, to their quantivalence. For example, one atom of Mg or of Ba may replace one atom of Ca , all being dyads; but two atoms of Na (monad) are required to replace one of Ca ; similarly three dyad atoms are equivalent, or may replace, one hexad atom, thus, $3 \mathrm{Ca}=\left[\mathrm{Al}_{2}\right]$.

The relation of the different oxides may be understood from the following scheme, in which the above principle is made use of. The line A below contains the different kinds of oxides. B the same divided each by its number of atoms of oxygen (that is, severally, for the successive terms, by $1,3,2,5,3,7,4$, by which division they are reduced to the protoxide form. C the basic elements alone:

| A | RO | $\mathrm{R}^{2} \mathrm{O}^{3}$ | $\mathrm{RO}^{2}$ | $\mathrm{R}^{2} \mathrm{O}^{5}$ | $\mathrm{RO}^{3}$ | $\mathrm{R}^{2} \mathrm{O}^{7}$ | R()$^{4}$ |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| B | RO | $\mathrm{R}^{\frac{3}{3}}$ | $\mathrm{R}^{\frac{1}{2}} \mathrm{O}$ | $\mathrm{R}^{\frac{2}{5}} \mathrm{O}$ | $\mathrm{R}^{\frac{1}{1}} \mathrm{O}$ | $\mathrm{R}^{\frac{2}{7}} \mathrm{O}$ | $\mathrm{R}^{\frac{1}{4}}$ |
| C | R | $\mathrm{R}^{\text {a }}$ | $\mathrm{R}^{\frac{1}{2}}$ | $\mathrm{R}^{\text {\% }}$ | $\mathrm{R}^{\frac{1}{3}}$ | $\mathrm{R}^{\frac{2}{7}}$ | $\mathrm{R}^{\frac{1}{4}}$ |

According to the above law the $R, R^{\sharp}, R^{\ddagger}$, etc., in the last line, are mutuaily replaceable, 1 for 1 , thongh varying in atomic weight from 1 to $\frac{1}{4}$. They represent different states in which elements may exist, and have, to a certain extent, independent element-like relations. In some cases, as in iron, four of these states are represented in a single element, the compounds (1) $\mathrm{FeO}, \mathrm{FeS}$, (2) $\mathrm{Fe}^{2} \mathrm{O}^{3}$, (3) $\mathrm{FeS}^{3}$, (4) $\mathrm{FeO}^{3}$, containing this metal in four states $\mathrm{Fe}, \mathrm{Fe}^{\mathrm{i}}, \mathrm{Fe}^{\frac{1}{4}}, \mathrm{Fe}^{\frac{1}{2}}$.

The use of the fractions can be avoided by multiplying, instead of dividing, thus, $\mathrm{Fe}^{\mathrm{t}}$ of $\mathrm{Fe}^{2} \mathrm{O}^{3}$ replaces Fe of FeO , we might have said, 2 Fe of $\mathrm{Fe}^{2} \mathrm{O}^{3}$ replaces 3 Fe of $\mathrm{FeO}\left(\mathrm{Fe}^{2} \mathrm{O}^{3}, \mathrm{Fe}^{3} \mathrm{O}^{3}\right)$, and so for the others.

These different states of the elements are best designated in the symbols
by the Greek letters $a, \beta$, etc., thus avoiding all ecnfusion. The above lines $A, B, C$ then become

| A | $a \mathrm{RO}$ | $3 \beta \mathrm{RO}$ | $2 \gamma \mathrm{RO}$ | $5 \delta \mathrm{RO}$ | $3 \in \mathrm{RO}$ | $7 \xi \mathrm{RO}$ | $4 \eta \mathrm{RO}$ |
| :--- | :--- | :---: | :---: | :---: | :---: | :---: | :---: |
| B | $a \mathrm{RO}$ | $\beta \mathrm{RO}$ | $\gamma \mathrm{RO}$ | $\delta \mathrm{RO}$ | $\in \mathrm{RO}$ | $\zeta \mathrm{RO}$ | $\eta \mathrm{RO}$ |
| O | $a \mathrm{R}$ | $\beta \mathrm{R}$ | $\gamma \mathrm{R}$ | $\delta \mathrm{R}$ | $\epsilon \mathrm{R}$ | $\zeta \mathrm{R}$ | $\eta \mathrm{R}$ |

By means of this system all the different oxides may be reduced to tho common protoxide form, and thus the true relations of the silicates may bo clearly expressed. This is exhibited in the formulas for the silicates given in Dana's System of Mineralogy (1868).

Calculation of a formula from an analysis.-The result of an analysis gives the proportions, in a hundred parts of the mineral, of either the elements themselves, or of their oxides or other compounds obtained in the chemical analysis. In order to obtain the atomic proportions of the elements: Divide the percentages of the elements by the respective a томाо weignts; or, for thase of the oxides: Divide the percentage amounts of each by their molecular weights; then, find the simplest ratio in whole numbers for the numbers thus obtained.

Examples.-An analysis of bournonite from Meiseberg gave Ramınelsberg: Lead ( Pb ) $42 \cdot 38$, copper ( Cu ) $13 \cdot 06$, antimony ( Sb ) $24 \cdot 34$, and sulphur (S) $19 \cdot 76=100 \cdot 04$. Dividing each amount by its atomic weight we sbtain :

$$
\frac{42 \cdot 8 ;}{207}=\cdot 207 ; \quad \frac{13 \cdot 06}{63 \cdot 4}=\cdot 206 ; \quad \frac{24 \cdot 34}{122}=\cdot 217 ; \quad \frac{19 \cdot 76}{32}=\cdot 6175
$$

The atomic ratio is hence $:-\mathrm{Pb}: \mathrm{Cu}: \mathrm{Sb}: \mathrm{S}={ }^{-207}: \cdot \cdot 206: \cdot 217: \cdot 6175$; that is, $1.005: 1: 1.053: 2 \cdot 998$, or in whole numbers, $1: 1: 1: 3$. The empirical formula is consequently $\mathrm{CuPbSbS}_{3}$.

An analysis of epidote from Untersulzbach gave Ludwig:

| $\mathrm{SiO}_{2}$ | $\mathrm{AlO}_{3}$ | FeO |  |  |  |
| :--- | :--- | :--- | :--- | :--- | :--- |
| $37 \cdot 83$ | $22 \cdot 63$ | $15 \cdot 02$ | FeO | CaO | CaO <br> $23 \cdot 27$ |
| $2 \cdot 05=101 \cdot 73$. |  |  |  |  |  |

From the results of the analysis given in this form, the percentage amount of each element may be calculated in the usual way; we obtain: Si $17 \cdot 65$, $\mathrm{Al} 12 \cdot 06, \mathrm{Fe} 10 \cdot 51$, $\mathrm{FeO} 0 \cdot 72$, $\mathrm{Ca} 16 \cdot 62$, H $0.23, \mathrm{O} 43 \cdot 64$. The number of atoms of each element may be calculated from the last given percentages by dividing each by the atomic weight, that is $\frac{17 \cdot 6 \breve{5}}{28}=\cdot 630$ for $\mathrm{Si}, \frac{12 \cdot 06}{55}=0.22$ for $\mathrm{Al}\left(=\mathrm{Al}_{2}\right)$, etc. Or, the percentage amounts of each oxide may be divided by its molecular weight, and the result will be the same; for $\mathrm{SiO}_{2}$, the molecular weight is $60(28+2 \times 16)$, hence, $\frac{37 \cdot 83}{60}=\cdot 630$ as before; also for $\mathrm{Al}, 103(=2 \times 27 \cdot 5+3 \times 16)$, and $\frac{22 \cdot 63}{103}=0 \cdot 22$, etc. The atomic proportions thus obtained are:

| $\underset{0.630}{\mathrm{Si}}$ | $\begin{gathered} \mathrm{Al} \\ 0 \cdot 220 \end{gathered}$ | $\begin{gathered} \mathrm{Fe} \\ 0.094 \end{gathered}$ | $\underset{0.013}{\mathrm{Fe}}$ | $\underset{0 \cdot 415}{\mathrm{Ca}}$ | $\underset{0 \cdot 230}{\mathrm{H}}$ | $\underset{2 \cdot 727, \text { or simply }}{\mathbf{O}}$ |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | $\cdot 314$ |  | $0 \cdot 428$ |  |  |  |
|  |  |  | $4 \cdot 07$ |  | $2 \cdot 2$ | $25 \cdot 79$, or ayain |
| 6 | 3 |  |  |  | 2 | 26. |

The empirical formula is consequently $\mathrm{Si}_{6} \mathrm{Al}_{3} \mathrm{Ca}_{4} \mathrm{H}_{2} \mathrm{O}_{26}$. As in the above case, it is necessary, when very small quantities only of certain elements are present, to neglect them in the final formula, reckoning them in with the elements which they replace, that is, with those of the same quantivalence. The degree of correspondence between the analysis and the formula deduced, if the latter is correctly assumed, depends entirely upon the accuracy of the former.

Quantivalent Ratio.-In the chemical constitution of most minerals there exists a strong distinction between the basic and acidic elements, and this relation, in the case of substances of complex character, is often fixed when otherwise the composition is exceedingly varied. In the dualistic formulas of the old chemistry this relation was expressed in the " oxygenratio," which gave the ratio between the number of oxygen atoms belonging respectively to the bases, protoxide and sesquioxide, and to the acid. The expression, "oxygen-ratio," is not in harmony with the present method of viewing chemical compounds, and the term has consequently been, to some extent, abandoned; the same relation, however, between the different classes of elements still exists, but the ratio must be regarded as that existing between the total quantivalences of each group of elements, and hence may be called the Quantivalent Ratio.*

The old formula for all the members of the garnet family is $3 \dot{\mathrm{R}}, \not{\mathrm{H}}, 3 \ddot{\mathrm{~S}} \mathrm{i}$ $=3 \mathrm{RO}, \mathrm{RO}_{3}, 3 \mathrm{SiO}_{2}$, and the oxygen ratio for $\mathrm{R}: \ddot{\mathrm{Z}}: \ddot{\mathrm{Si}}=1: 1: 2$, or for bases to silica, $1: 1$. Here $\dot{\mathrm{R}}$ may be either $\dot{\mathrm{C}}$, $\dot{\mathrm{M}} \mathrm{g}, \dot{\mathrm{F}}$, $\dot{\mathrm{M}}_{\mathrm{n}}$, or $\dot{\mathrm{Cr}}$, and $\ddot{\mathrm{H}}$ either $\dddot{\AA} 1, \dddot{\mathrm{~F}}$ e, $\not \mathrm{O} \mathrm{r}$. This formula, however, written according to the new system (the quantivalence being expressed by Roman numerals over the symbols), is:
to indicate that the oxygen is regarded as all linking oxygen. The ratio of the total quantivalences for each class of elements, dyads and hexads (basic), and the tetrad silicon (acidic), is: $-3 \times \mathrm{II}: \mathrm{VI}: 3 \times \mathrm{IV}$, or, Q. ratio, for $R: \mathrm{R}:$ Si $\dagger=6: 6: 12$, that is, $1: 1: 2$.

The same ratio for $(R+R): S i=1: 1$, both of which are identical with the previously given oxygen ratio.

[^28]Thus the oxygen ratio of the old system becomes the quantivalent ratio of the new, "a term, too, which has a wider meaning and bearing than that which it replaces." This principle of the ratio between the total quantivalences is an important one, and fundamental in the character of chemical compounds. This is well shown in the example here given, where, for a family of minerals of so varied composition as the garnets, it remains constant in all varieties. Its importance is even more marked in the many silicates where R replaces 3 R (as in spodumene in the pyroxene family).

The quantivalent ratio is obtained by multiplying the quantivalence of each class of elements present by their number of atoms; or by dividing. the percentage anount of each element by the atomic weight and multiply by its quantivalence. When the basic or acid oxides are given, divide the percentage amount of each by the molecular weight, and multiply as before by the number expressing the quantivalence, and the result is the total quantivalence for the given element.

## Dinorphism. Isomorpiism.

A chemical compound, which crystallizes in two forms genetically distinct, is said to be dimorphous; if in three, trimorphous, or in general pleomorphous. The phenomenon is called dmorphism, or pleomorphism.

On the other hand, chemical compounds, which are of dissimilar thongh analogons composition, are said to be isomorphous when their crystalline forms are identical, or at least very closely related (sometimes called homoomorphons). This phenomenon is called isomorphism.

An example of pleomorphism is given by the compond calcium carbonate $\left(\mathrm{CaCO}_{3}\right)$, which is trimorphous: appearing as calcite, as aragonite, and as baryto-calcite. As calcite, it crystallizes in the rhombohedral system, and, unlike as its many crystalline forms are, they may be all referred to the same fundamental rhombohedron, and, what is more, they have all the same cleavage and the same specific gravity ( $2 \cdot 7$ ), and, of course, the same optical characters. As aragonite, calcinm carbonate appears in orthorhombic crystals, whose optical characters are entirely different from those of calcite, as will be understood from the explanations made in the preceding chapter. Moreover, the specific gravity of aragonite (29) is higher thau that of calcite $(2 \cdot 7)$. Again, as baryto-calcite, calcium carbohate crystallizes in a monoclinic form.

The explanation of the phenomenon of pleomorphism in this case-and an analogous explanation must answer for all such cases-is to be found, not as was once proposed in a slight variation of chemical composition, but in the different conditions in which the same componnd has been formed. Thus Rose has shown that the calcium carbonate precipitated from a solution by the alkaline carbonates in the cold has the form of calcite, whereas, if the precipitation takes place at a temperature of $100^{\circ} \mathrm{C}$., it takes the firm of aragonite. Moreover, he found that aragonite on heating fell to powder, and though no loss of weight took place, the specific gravity ( $\% \cdot 9$ ) became that of calcite $(2 \cdot \gamma)$.

Many other examples of pleomorphism may be given: Silica $\left(\mathrm{SiO}_{2}\right)$ is trimorphous; appearing as quartz, rhombohedral, $\mathrm{G}=2.66$; as tridymite,
hexagonal, $\mathrm{G}=2 \cdot 3$; and as asmanite, orthorhombic, $\mathrm{G}=2 \cdot 24 \quad$ Titanic oxide $\left(\mathrm{TiO}_{2}\right)$ is also trimorphous, the species being called rutile, tetragonal $(\dot{c}=\cdot 6442), \mathrm{G}=4 \cdot 25$; octahedrite $(\dot{c}=1 \cdot 778), \mathrm{G}=3 \cdot 9$; and brookite, orthorhombic or monoclinic, $G=4 \cdot 15$. Carbon appears in two forms, in diamond and graphite. Other familiar examples are pyrite and marcasite $\left(\mathrm{FeS}_{2}\right)$; acanthite and argentite ( $\mathrm{Ag}_{2} \mathrm{~S}$ ) ; sphalerite and würtzite ( ZnS ) ; sulphur natural, orthorhombic, if artificial and crystallizing from a molten condition, monoclinic. The relation in form of the species mentioned, and also of those of other dimorphous groups, will be found in Part III., Descriptive Mineralogy.

Isomorphism is well illustrated by the group of rhombohedral carlonates, with the general formula $\mathrm{RCO}_{3}$. Here R may be $\mathrm{Ca}, \mathrm{Mg}, \mathrm{Fe}, \mathrm{Mn}$, or Zn ; or further, in the same species, the R may be represented by both Ca and Mg in rarying proportions, as remarked on the following page, or both Ca and Fe , etc. The group is as follows:

| Calcite. | Dolomite. | Magnesite. | Rhodochrosite. | Siderite. | Smithsonite. |
| :---: | :---: | :---: | :---: | :---: | :---: |
| $\mathrm{CaCO}_{3}$ | $\left.\begin{array}{l} \mathrm{Ca} \\ \mathrm{M}{ }^{\circ} \end{array}\right\} 2 \mathrm{CO}_{3}$ | $\mathrm{MgCO}_{3}$ | $\mathrm{MnCO}_{3}$ | $\mathrm{FeCO}_{3}$ | $\mathrm{ZnCO}_{3}$ |
| $105^{\circ} 5^{\prime}$ | $106^{\circ} 15^{\prime}$ | $107^{\circ} 29^{\prime}$ | $106^{\circ} 51^{\prime}$ | $107^{\circ} 0^{\prime}$ | $107^{\circ} 40^{\prime}$. |

Ankerite (parankerite), breunerite, mesitite, and pistomesite belong to the same group. All the above species have an analogous composition, and all crystallize in the rhombohedral system, the angle of the fundamental form varying somewhat in the different cases.

Mitscherlich, who, by a series of experimental researches, established the principle of isomorphism, expressed it as follows: Substances, which are analogous chemical compounds, have the same crystalline form, or are isomorphous.

Some of the more important isomorphous groups are mentioned below, for the description of the different species reference must be made to Part III.

Isometric system.-(1) The spinel group, having the general formula $\mathrm{RRO}_{4}$, including spinel $\mathrm{MgAlO}_{4}$, magnetite $\mathrm{FeFeO}_{4}$, chromite $\mathrm{Fe} \mathrm{ErO}_{4}$, also franklinite, gahnite, etc. (2) The alum group, for example, potash-alum $\mathrm{K}_{2} \mathrm{AlS}_{4} \mathrm{O}_{16}+24 \mathrm{aq}$, etc. (3) The Garnet group, having the general formula $\mathrm{R}_{3} \mathrm{FSi}_{3} \mathrm{O}_{12}$.

Tetragonal system.-Rutile group, $\mathrm{RO}_{2}$; including rutile $\mathrm{TiO}_{2}$, and cassiterite $\mathrm{SnO}_{2}$. The scheelite group; including scheelite $\mathrm{CaWO}_{4}$, stolzite $\mathrm{PbWO}_{4}$, wulfenite $\mathrm{PbMO}_{4}$.

Hexagoncel, system.-Apatite group; apatite $3 \mathrm{Ca}_{3} \mathrm{P}_{2} \mathrm{O}_{8}+\mathrm{Ca}(\mathrm{Cl}, \mathrm{F})_{2}$, pyrosnorphite $3 \mathrm{~Pb}_{3} \mathrm{P}_{2} \mathrm{O}_{8}+\mathrm{PbCl}_{2}$, mimetite $3 \mathrm{~Pb}_{3} \mathrm{As}_{2} \mathrm{O}_{8}+\mathrm{PbCl}_{2}$, and vanadinite $3 \mathrm{~Pb}_{3} \mathrm{~V}_{2} \mathrm{O}_{8}+\mathrm{PbCl}_{2}$. Corundum group, $\mathrm{RO}_{3}$; corundum $\mathrm{AlO}_{3}$, hematite $\mathrm{FeO}_{3}$, menaccanite.

Rhombohedral system.-Calcite group, $\mathrm{RCO}_{3}$, already mentioned.
Orthorhombic system.- Aragonite group, $\mathrm{RCO}_{3}$; aragonite $\mathrm{CaCO}_{3}$, witherite $\mathrm{BaCO}_{3}$, strontianite $\mathrm{SrCO}_{3}$, cerussite $\mathrm{PbCO}_{3}$. Barite group, $\mathrm{RSO}_{4}$; barite $\mathrm{BaSO}_{4}$, celestite $\mathrm{SrSO}_{4}$, anhydrite $\mathrm{CaSO}_{4}$, anglesite $\mathrm{PbSO}_{4}$. Chrysourre group, general formula, $\mathrm{R}_{2} \mathrm{SiO}_{4}$.

Monoclinic system.--Copperas group; melanterite $\mathrm{FeSO}_{4}+7 \mathrm{aq}$; biebcrite $\mathrm{CoSO}_{4}+7 \mathrm{aq}$, etc. Pyroxene group, $\mathrm{RSiO}_{3}$, etc.

Monoclinic and Triclinic. Feldspar group.
The above enumeration includes only the more prominent among the isomorphous groups. In many other cases a close relationship exists among species, both in form and composition, as brought out in Dana's System of Mineralogy (1854), and as also to some extent exhibited in the grouping of the species in the descriptive part of this work.
(1) It will be observed in the above that a replacement of an element in a compound by one or more other elements, chemically equivalent, may take place without any essential change of the crystalline form. Besides this a part of one element may be similarly replaced. This is illustrated in the case of the rhombohedral carbonates: calcite has the composition $\mathrm{CaCO}_{3}$, and magnesite $\mathrm{MgCO}_{3}$; but in dolomite the place of the basic element is taken by Ca and Mg in equal proportions, so that the formula may be written $\left(\frac{1}{2} \mathrm{Ca}+\frac{1}{2} \mathrm{Mg}\right) \mathrm{CO}_{3}$, or more properly $\mathrm{CaMgC}_{2} \mathrm{O}_{6}$. But besides this compound there are others where the ratio of Ca to Mg is $3: 2$, also $2: 1$, and $3: 1$, etc. Further than this the Ca or Mg may be in part replaced by $\mathrm{Mn}, \mathrm{Fe}$, or Zn .

The mineral ankerite is one in which $\mathrm{Ca}, \mathrm{Mg}, \mathrm{Fe}(\mathrm{Mn})$, all enter, and in different proportions. Boricky has shown that the composition of the ankerite group of compounds is expressed by the formula : $-\mathrm{CaCO}_{3}+\mathrm{FeCO}_{3}$ $+x\left(\mathrm{CaMgC}_{2} \mathrm{O}_{6}\right)$, where $x$ may be $\frac{1}{2}, 1, \frac{4}{3}, \frac{3}{2}, \frac{5}{3}, 2,3,4,5,10$. This and all similar cases are examples of isomorphous replacement.

It is not essential that the replacing elements in an isomorphous series should have the same quantivalence, although this is generally true. For example, spodumene is isomorphous with the pyroxene group, though in it the bivalent clement is replaced by a sexivalent $(3 R=\mathrm{Z})$. So, too, menaccanite was included in the corundum group, since here $\mathrm{RRO}_{3}$ is isomorphous with $\mathrm{ZO}_{3}$. This relation of the elements, which are not equivalent, is brought ont by the method of viewing the oxides presented on p. 174.
(2). Minerals which crystallize in different systems may yet be isomorphons, when the difference between their geometrical form is slight; this is conspicuously true of the members of the feldspar family.
(3). Minerals may be closely related in form, althongh there is no analogy whatever between their chemical composition; many such cases have been noted, e.g., axinite and glanberite, azurite and epidote.

Two substances may be both homœomorphous and correspondingly dimorphous; and they are then described as isodimorphous. Titanic oxide $\left(\mathrm{TiO}_{2}\right)$, and stannic oxide $\left(\mathrm{SnO}_{2}\right)$, are both dimorphons, and they are also homœomorphons severally in each of the two forms. This is an example of isodimorphism.

There are also cases of isotrimorphism. Thus there are the following related groups; the angle of the rhombohedral forms here given is $R: R$. of the orthorhombic and monoclinic $I: I$ (for baryto-calcite 2-2 on 2-2):

## $\mathrm{RCO}_{3}$ <br> $\mathrm{RSO}_{4}$ $\mathrm{RSO}_{4}+\mathrm{nRCO}_{3}$

Rhombohedral. Calcite, $105^{\circ} 5^{\prime}$. Dreelite, $93^{\circ}-94^{\circ}$. Susannite, $94^{\circ}$.

Orthorhombic. Aragonite, $116^{\circ} 10^{\prime}$. Anglesite, $103^{\circ} 38^{\prime}$. Leadhillite, $103^{\circ} 16^{\prime}$.

> Monodinic. Barytocalcite, $95^{\circ} 8^{\prime}$. Glauberite, $83^{\circ}-83^{\circ} 20^{\prime}$. Lanarkite, $84^{\circ}$.

Calcite, aragonite, and barytocalcite form an undoubted case of trimor $\dot{p h i s m}$, as has already been shown. Dreelite, anglesite, and glauberite constitute another like series, and moreover it is closely parallel in angle with the former. In the third line we have the sulphato-carbonate susannite near dreelite in angle, leadhillite (identical with susannite in composition) near anglesite, and lanarkite, another sulphato-carbonate, near glauberite, forming thus a third parallel line. The sulphuric acid in these sul-phato-carbonates dominates over the carbonic acid, and gives the form of the sulphates enumerated in the second line of the table.

## Chemical Examination of Minerals.

The chemical characters of minerals are ascertained $(a)$ by the action of acids and other reagents; (b) by means of the hlowpipe assisted by a few chemical reagents ; (c) by chemical analysis. The last method is the only one by which the exact chemical composition of a mineral can be determined. It belongs, however, wholly to chemistry, and it is unnecessary to touch upon it here except to call attention to the remarks already made (p.160) upon the essential importance of the use of pure material for analysis.

The various tests and reactions of the wet and dry methods are important, since they often make it possible to determine a mineral with very little labor, and this with the use of the minimum amount of material.

## a. Examination in the Wet Way.

The most common chemical reagents are the three mineral acids, hydrochloric, nitric, and sulphuric. In testing the powdered mineral with these acids, the important points to be noted are: (1) the degree of solubility, and (2) the phenomena attending entire or partial solution; that is, whether a gas is evolved, producing effervescence, or a solution is obtained without effervescence, or an insoluble constituent is separated out.

Solubility.-In testing the degree of solubility hydrochloric acid is most commonly used, thongh in the case of sulphides, and compounds of lead and silver, uitric acid is required. Less often sulphuric acid, and aqua regia (nitro-hydrochloric acid), are resorted to.

Many minerals are completely soluble vithout effervescence: among these are some of the oxides, hematite, limonite, göthite, etc., some sulphates, many phosphates and arseniates, etc.

Solubility with effervescence takes place when the mineral loses a gaseous ingredient, or when one is generated by the mutual decomposition of acid and mineral. Most conspicuous here are the carbonates, all of which dissolve with effervescence, giving off carbonic acid (properly carbon dioxide, $\mathrm{CO}_{2}$ ), though some of them only when pulverized, or again, on the addition of heat. In applying this test dilute hydrochloric acid is employed. Sulphuretted hydrogen $\left(\mathrm{H}_{2} \mathrm{~S}\right)$ is evolved by some sulphides, when dissolved in hydrochloric acid: this is true of sphalerite, stibnite, greenockite, etc. Chlorine is evolved by oxides of manganese and also chromic and vanadic acid salts, when dissolved in hydrochloric acid. Nitric peroxide is given off by many metallic minerals, and also some of the lower oxides (cuprite, etc.), when treated with nitric acid.

The separation of an insoluble ingredient takes place: With many silicates, the silica separating sometimes as a fine powder, and again as a jelly; in the latter case the mineral is said to gelatinize (sodalite, analcite). In order to test this point the finely pulverized silicate is digested with strong hydrochloric acid, and the solution afterward slowly evaporated nearly to dryness. With a considerable number of silicates the gelatinization takes place only after ignition; while others, which ordinarily gelatinize, are rendered insoluble by ignition.

With many sulphides a separation of sulphur takes place when they are treated with nitric acid. Compounds of titanic and tungstic acids are decomposed by hydrochloric acid with the separation of the oxides named. The same is true of salts of molybdic and vanadic acids, only that here the oxides are soluble in an excess of the acid.

Componuds containing silver, lead, and mercury give with hydrochloric acid insolnble residues of the chlorides. These componnds are, however, solnble in nitric acid.

When componnds containing tin are treated with nitric acid, the stannic oxide separates as a white powder. A corresponding reaction takes place under similar circumstances with minerals containing arsenic and antimony.

Insoluble minerals.-A large number of minerals are not sensibly attacked by any of the acids. Among these may be named the following oxides: cormndum, spinel, chromite, diaspore, rutile, cassiterite, quartz; also cerargyrite ; many silicates, titanates, tantalates, and columbates; also the sulphates (barite, celestite, anglesite); many phosphates (xenotime, lazulite, childrenite, amblygonite), and the borate, boracite.

## b. Examination of Minerals by means of the Blowpipe.

Blowpipc.-The simplest form of the blowpipe is a tapering tube of brass (f. 413, 1), with a minute aperture at the extremity. A chamber is advantageously added (f. 413, 2) at $o$, to receive the condensed moisture, and an ivory mouth-piece is often very convenient. In the better forms of the instrument (see f. 413, 3), the tip is made of solid platinum ( $f$ ), which admits of being readily cleaned when necessary. Operations with the blowpipe often require an unintermitted heat for a considerable length of time, and always longer than a single breath of the operator. It is therefore requisite that breathing and blowing should go on together. This may be difficult, at first, but the necessary skill or tact is soon acquired.

Blowpipe-flame.-The best and most convenient source of heat for blowpipe purposes is ordinary illuminating gas. The burner is a
 simple tube, flattened at the top, and cut off a little obliquely; it thus furnishes a flame of convenient shape. A similar
jet may also be used in conjunction with the ordinary Bunsen burner, it being so made as to slip down within the outer tube, and cut off the supply of air, thus giving a luminous flame. The gas flame required need not be more than an inch and a half in height. In place of the gas, a lamp fed with olive oil will answer, or even a good candle.

The jet of the blowpipe is brought close to the gas flame on the higher side of the obliquely terminated burner. The arm of the blowpipe is inclined a little downward, and the blast of air produces an oblique conical flame of intense heat. This blowpipe flame consists of two cones: an inner of a blue color, and an outer cone which is yellow. The heat is most intense just beyond the extremity of the blue flame, and the mineral is held at this point when its fusibility is to be tested.

The inner flame is called the reducing flame (R.F.); it is characterized by the excess of the carbon or hydrocarbons of the gas, which at the high temperature present tend to combine with the oxygen of the mineral brought into it, or in other words, to reduce it. The best reducing flame is produced when the blowpipe is held a little distance from the gas flame; it should retain the yellow color of the latter.

The outer cone is called the oxidizing flame (O.F.); it is characterized by the excess of the oxygen of the air over the carbon of the gas to be combined with it, and has hence an oxidizing effect upon the assay. This flame is best produced when the jet of the blowpipe is inserted a very little in the gas flaine; it should be entirely non-luminous.

Supports.-Of other apparatus required, the most essential articles are those which serve to support the mineral in the flame; these supports are: (1) charcoal, (2) platinum forceps, (3) platinum wire, and (4) glass tubes.
(1) Charcoal is especially useful as a support in the case of the examination of metallic minerals, where a reduction is desired. It must not crack when heated, and should not yield any considerable amount of ash on combustion; that made from soft wood (pine or willow) is the best. Pieces of convenient size for holding in the hand are employed; they should have a smooth surface, and a small cavity should be in it made for the mineral.
(2) A convenient kind of platinum forceps is represented in f. 414 ; it is made of steel with platinum points. These open by means of the pins

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$p p$; other forms open by the spring of the wire in the handle. Care must be taken not to heat any substance (e.g., metallic) in the forceps, which when fused might injure the platinum.
(3) Platinum wire is employed with the use of fluxes, as described in another place.
(4) The glass tubes required are of two kinds: closed tubes, having only one open end, about fonr inches long; and open tubes, having both ends open, four to six inches in length. Both kinds can be easily made by the student from ordinary tubing (hest of rather hard glass), having a bore of $\frac{1}{2}$ to $\frac{1}{8}$ of an inch.

In the way of additional apparatus, the following articles are useful; they need no special deseription : haminer, small anvil, three-cornered file, magnet, pliers, pocket-lens, and a small mortar, as also a few of the test-tubes. etc., used in the laboratory.

Chemical reagents.-The commonest reagents employed are the fluxes: viz., soda (sodium carbonate) ; salt of phosphorus (sodium-ammonium phosphate) ; and borax (sodium biborate). The method of using them is spoken of on p. 208.

Nitrate of cobalt in solution is also employed. It is conveniently kept in a small bulb from which a drop or two may be obtained as it is needed. This is used principally as a test for aluminum or magnesium with infusible minerals, as remarked beyond. The fragment of the mineral held in the forceps is first ignited in the blowpipe flame, a drop of the cobalt solution is placed on it, and then it is heated again ; the presence of either constitnent named is manifested by the color assumed by the ignited mineral. It is also used as a test for zinc. Potassium bisulphate and calcium fluoride (fluorite) in powder, metallic magnesiun (foil or wire), and tin foil, are other reagents, the use of which is explained later. Test-papers are alsu needed, viz, blue litinns paper, and turmeric paper.

The wet reagents required are: the ordinary acids, and most important of these hydrochloric acid, generally diluted one-half for use, and alsa barium chloride, silver nitrate, ammonium molybdate.

The blowpipe investigation of minerals includes their examination, (1) in the platinum-pointed forceps, (2) in the closed tube, (3) in the open tube, (4) on charcoal, and (5) with the fluxes.
(1) Examination in the forceps.-The most important use of the plati-num-pointed forceps is to hold the fragment of the mineral while its fusibility is tested.


#### Abstract

The following practical points must be regarded : (1) Metallic minerals, which when fused may injure the platinum, should be examined on charcoal; (2) the fragment taken should be thin, and as small as can conveniently be held; (3) when decrepitation takes place, the heat must be applied slowly, or, if this does not prevent it, the mineral may be powderel and a paste made with water, thick enough to be held in the forceps or on the platinum wire; or the paste may, with the same end in view, be heated on charcoal ; (4) the fragnent whose fusibility is to be tested must be held in the hottest part of the flame, just beyond the extremity of the blue cone.


In connection with the trial of fusibility, the following phenomena may be observed: (a) a coloration of the flame; (b) a swelling up (stilbite), or an exfoliation of the mineral (vermiculite); or (c) a glowing without fusion (calcite) ; and $(d)$ an intumescence, or a spirting out of the mass as it fuses (scapolite). The color of the mineral after ignition is to be noted; and the nature of the fused mass is also to be observed, whether a clear or blebby giass is obtained, or a black slag, or whether magnetic or not, etc.

The ignited fragment, if nearly or quite infusible, may be moistened with the cobalt solution and again ignited (see above) ; also, if not too fusible, it may, after treatment in the forceps, be placed upon a strip of moistened turmeric paper, in which case an alkaline reaction shows the presence of the alkaline earths.

Fusibility.-All grades of fusibility exist among minerals, from those
which fuse in large fragments in the flame of the candle (stibnite, see below), to those which fuse only on the thinnest edges in the hottest blowpipe flame (bronzite); and still again there are a considerable number which are entirely infusible (e.g., corundum).

The following scale of fusibility, proposed by von Kobell, is made use of : 1, stibnite ; 2, natrolite ; 3, almandine garnet ; 4, actinolite ; 5, orthoclase; 6 , bronzite.

A little practice with these minerals will show the student what degree of fusibility is expressed by each number, and render him quite independent of the table; he will thus be able also to judge of his power to produce a hot flame by the blowpipe, which requires practice.

Flame coloration.-When coloration is produced it is seen on the exterior portion of the flame, and is best observed when shielded from the direct light.

The presence of soda, even in small quantities, produces a yellow flame, which (except in the spectroscope) more or less completely masks the coloration of the flame due to other substances; phosphates and borates give the green flame in general best when they have been pulverized and moistened with sulphuric acid; moistening with hydrochloric acid makes the coloration in many cases (barium, strontium) more distinct.

The colors which may be produced, and the substances to whose presence they are due, are as follows: (1) yellow, sodium; (2) violet, potassium; (3) purple-red, lithium; red, strontium; yellowish-red, calcium (lime); (4) yellowish-green, barium, molybdenum; emerald-green, copper; bluishgreen, phosphorus (phosphates) ; yellowish-green, boron (borates); (5) blue, azure-blue, copper chloride; light-blue, arsenic ; greenish-blue, antimony.
(2) Heating in the closed tube. The closed tube is employed to show the effect of heating the mineral out of contact with the air. A small frag. ment is taken, or sometimes the powdered mineral is inserted, though in this case with care not to soil the sides of the tube. The phenomena which may be observed are as follows: decrepitation, as shown by fluorite, calcite, etc.; glowing, as exhibited by gadolinite; phosphorescence, of which fluorite is an example; change of color (limonite), and here the color of the mineral should be noted both when hot, and again after cooling ; fusion ; giving off oxygen, as mercuric oxide; yielding water at a low or high temperature, which is true of all hydrous minerals; yielding acid or alkaline vapors, which should be tested by inserting a strip of moistened litmus or turmeric paper in the tube; yielding a sublimate, which condenses in the cold part of the tulue.

Of the sublimates which form in the tube, the following are those with which it is most important to be familiar: Sublimate yellow, sulphur; dark brown-red when hot, and red or reddish-yellow when cold, arsenic sulphide; brilliant black, arsenic (also giving off a garlic odor); black when hot, brown-red when cold, formed near the mineral by strong heating, antimony oxysulphide; dark-red, selenium (also giving the odor of decaying horseradish); sublimate consisting of small drops with metallic lustre, tollurium; sublimate gray, made up of minute metallic globules, mercury; subinmate black, lustreless, red when rubbed, mercury sulphide.
(3) Heating in the open tube.-The small fragment is placed in the tube about an inch from the lower end, the tube being inclined sufficiently to present the mineral from slipping out. The current of air, passing through
the tube during the heating process, has an oxidizing effect. The special phenomena to be observed are the formation of a sublimate and the odor of the escaping gases. The acid or alkaline character of the vapors are tested in the same way as with the closed tube. Fluorides, when heated in the open tube with previously fused salt of phosphorus, yield hydrofluoric acid, which gives an acid reaction with test-paper, has a peculiar pungent odor, and corrodes the glass.

The sublimates which may be formed, as far as they differ from those already mentioned, as obtained in the closed tube, are as follows: Sublimate, white and crystalline, volatile, arsenous oxide; white, near the mineral crystalline, fusible to minute drops, yellowish when hot, nearly color less when cold, molybdic oxide; sublimate white, yielding dense white fumes, at first mostly volatile, forming on the upper side of the tube, and afterward generally non-volatile on the under side of the tube, antimonous and antimionic oxides; sublimate dark brown when hot, lemon-yellow when cold, fusible, bismuth oxide ; sublimate gray, fusible to colorless drops, tellurous oxide ; sublinate steel-gray, the upper edge appearing red, selenium ; sublimate bright metallic, mercury.

The odors which may be perceived are the same as those mentioned in the following article.
(4) Heating alone on charcoal. -The substance to be examined is placed in a shallow cavity; it may simply be a small fragment, or, where the mineral decrepitates, it may be powdered, mixed with water, and thus the material employed as a paste. The points to be noticed are:
(a) The odor given off after short heating. In this way the presence of sulphur, arsenic (garlic odor), and selenium (odor of decayed horseradish), may be recognized.
(b) Fusion.-In the case of the salts of the alkalies the fused mass is absorbed into the charcoal; this is also true, after long heating, of the carbonates and sulphates of barium and strontium.
(c) The infusible residue.-This may (1) glow brightly in the O.F., indicating the presence of calcinm, strontium, magnesium, zirconium, zinc, or tin. (2) It may give an alkaline reaction after ignition: alkaline earths. (3) It may be magnetic, showing the presence of iron.
(d) The sublimate.-By this means the presence of many of the metals may be determined. The color of the sublimate, both near the assay ( N ), and at a distance (D) ; as also when hot and when cold is to be noted.

The most important of the sublimates, with the metals to which they are due, are contained in the following list: Sublimate, steel-gray (N), and dark gray (D), in R.F. volatile with a bluc flame, selenium (also giving a peculiar odor) ; white ( N ) and red or deep vellow (D), in R.F. volatile with green flane, tellurium ; white ( N ) and grayish ( D ), arsenic (giving also a peculiar alliaceous odor) ; white (N) and bluish (D), antimony (also giving off dense white fumes). Reddish-brown, silver ; dark orange-yellow when hot, and lemon-yellow when cold (N), also bluish-white (D), bismuth ; dark lemon-yellow when hot, sulphur-yellow when cold, lead; red-brown (N) and orange-yellow (D), cadmium ; yellow when hot, white on cooling, zinc (the sublimate becomes green if moistened with cobalt solution and again ignited) ; faint yellow when hot, white on cooling, tin (the sublimate jecomes bluish-green when ignited after being moistened with the cobalt

Bolition, in the R.F. it is reduced to metallic tin) ; yellow, sometimes crys talline when hot, white when cold (N), bluish (D), molybdenum (is O.F the sublimate volatilizes, leaving a permanent stain of the oxide, in R.F. gives an azure blue color when touched for a moment with the flame):
(5) Treatment with the fluxes.-The three fluxes have been mentioned on p. 205. They are used either on charcoal or with the platinum wire. If the latter is employed it must have a small loop at the end ; this is heated to redness and dipped into the powdered flux, and the adhering particles fused to a bead ; this operation is repeated until the loop is filled. Sometimes in the use of soda the wire may at first be moistened a little to cause it to adhere. When the bead is ready it is, while hot, brought in contact with the powdered mineral, some of which will adhere to it, and then the heating process may be contimed. Very little of the mineral is in general required, and the experiment should be commenced with a minute quantity and more added if necessary. The bead must be heated successively in the reducing and oxidizing flames, and in each case the color noted when hot and when cold. The phenomena connected with fusion, if it takes place, must also be observed.

Minerals containing sulphur or arsenic, or both, must be first roasted, that is, heated on charcoal, first in the oxidizing and then in the reducing flame, till these substances have been volatilized. If too much of the mineral has been added and the bead is hence too opaque to show the color. it may, while hot, be flattened out with the hammer, or drawn out into a wire, or part of it may be removed and the remainder diluted with more of the flux.

Borax.-The following list enumerates the different colored beads obtained with borax, and also the metals to the presence of whose cxides the colors are due:

Colorless ; silica, aluminum, the alkaline earths, etc. (both O.F. and R.F.) ; also silver, zinc, cadmium, lead, bismuth, and nickel, O.F., and also R.F., after long heating, but when first heated, gray or turbid ; R.F., manganese.

Yellow; in O.F., titanium, tungsten, and molybdenum, also zinc and cadminm, when strongly saturated and hot; vanadium (greenish when hot) ; iron, uraninm, and chromium, when feebly saturated.

Red to brown ; in O.F., iron, hot (on cooling, yellow) ; O.F., chromium, hot (yellowish-green when cold) ; O.F., uranium, hot (yellow when cold); nickel, manganese, cold (violet when hot).

Red ; R.F., copper, if highly saturated, cold (colorless when hot).
Violet ; O.F., nickel, hot (red-brown to brown on cooling) ; O.F., manganese.

Blue; O.F. and R.F., cobalt, both hot and cold; O.F., copper, cold (when hot, green).

Green ; O.F., copper, hot (blue or greenish-blue on cooling), R.F., bottlegreen; O.F., chromium, cold (yellow to red when hot), R.F., emerald-green: O.F., vanadium, cold (yellow when hot), R.F., chrome-green, cold (browuish when hot) ; R.F., uranium, yellowish-green (when highly saturated).

Salt of Phosphorus.-This flux gives for the most part reactions similar to those obtained with borax. The only cases enumerated here are those which are distinct, and hence those where the flux is a good test.

With silicates this flux forms a glass in which the bases of the silicate
are dissolved, bat the silica itself is left insoluble. It appears as a skeleton readily seen floating about in the melted bead.

The colors of the beads and the metals to whose oxides these are due, are:
Blue ; R.F., tungsten, cold (brownish when hot) ; R.F., columbium, cold and when highly saturated (dirty-blue when hot). Both these give colorless beads in the O.F.

Green ; R.F., uranium, cold (yellowish-green when hnt); O.F., molybdenum, pale on cooling, also R.F., dirty-green when hot, green when cold.

Violet ; R.F., columbium (see above); R.F., titanium cold (ycllow when hot).

Sona is especially valuable as a flux in the case of the reduction of the metallic oxides; this is usually performed on charcoal. The finely pulverized mineral is intimately mixed with soda, and a drop of water added to form a paste. This is placed in a cavity in the charcoal, and subjected to a strong reducing flame. More soda is added as that present sinks into the coal, and, after the process has been continued some time, the remainder of the flux, the assay, and the surrounding coal are cut out with a knife, and the whole ground up in a mortar, with the addition of a little water. The charcoal is carefully washed away and the metallic globules, flattened out by the process, remain behind. Some metallic oxides are very readily reduced, as lead, while others, as copper and tin, require considerable skill and care.

The metals obtained may be: iron, nickel, or cobalt, recognized by their being attracted by the magnet ; or copper, marked by its red color ; bismuth and antimony, which are brittle ; gold or silver ; antimony, tellurium, bismuth, lead, zine, cadmium, which volatilize more or less completely and may be recognized by their sublimates (see p. 207) ; arsenic and mercury are also reduced, but must be heated with soda in the closed tube in order to collect the sublimates. The metals obtained may be also tested with borax on the platinum wire.

By means of soda on charcoal the presence of sulphur in the sulphates may be shown, thongh they do not yield it upon simple heating. When soda is fused on charcoal with a compound of sulphur (sulphide or sulphate), sodium sulphide is formed, and if mnch sulphur is present the mass will have the hepar (liver-brown) color. In any case the presence of the sulphur is shown by placing the fused mass on a clean surface of silver, and adding a drop of water; a black or yellow stain of silver sulphide will be formed. Illuminating gas often contains sulphur, and hence, when it is used, the soda should be first tried alone on charcoal, and if a sulphur reaction is obtained (due to the gas), a candle or lamp must be employed in the place of the gas

It is also useful in the case of many minerals to test their fusibility or infusibility with soda, generally on the platinum wire. Silica forms if not in excess a clear glass with soda, so also titanic acid. Salts of barium and strontium are fusible with soda, but the mass is absorbed by the coal. Many silicates, though alone difficultly fusible, dissolve in a little soda to a clear glass, but with more soda they form an infusible mass. Manganese, when present even iu minute quantities, gives a bluish-green color to the soda bead.

## Characteristic Reactions of the most Important Elements and ow some of their Compounds.

The following list contains the most characteristic reactions, both before the blowpipe (B.B.) and in some cases in the wet way, of the different elements and their oxides. It is desirable for every student to be familiar with them. Many of them have already been briefly mentioned in the preceding pages. It is to be remembered that while the reaction of a single substance may be perfectly distinct if alone, the presence of other substances may more or less entirely obscure these reactions; it is consequently obvious that in the actual examination of minerals precautions have to be taken, and special methods have to be devised, to overcome the difficulty arising from this canse. These will be gathered from the pyrognostic characters given (by Prof. Brush) in connection with the description of each species in the Third Part of this work.

For many substances the most satisfactory and delicate tests are those which have been given by Bunsen in his important paper on Flane-reactions (Flammenreactionen, Ann. Ch. Pharm., cxxxviii., 257, or Phil. Mag., IV., xxxii., 81). The methods, however, require for the most part much detailed explanation, and in this place it is only possible to make this general reference to the subject.

Alumina. B.B.; the presence of alumina in most infusible minerals, containing a considerable amomnt, may be detected by the blue color which they assume when, after being heated, they are moistened with cobalt solution and again ignited. Very hard minerals (e.g., corundum) must be first finely pulverized.

Antimony. B.B.; antimonial minerals on charcoal give dense white inodorous fumes. Antimony sulphide gives in a strong heat in the closed tube a sublimate, black when hot, brown-red when cold. See also p. 207.

In nitric acid compounds containing antimony deposit white antimonic oxide $\left(\mathrm{Sb}_{2} \mathrm{O}_{5}\right)$.

Arsenic. 13.B.; arsenical minerals give off fumes, usually easily recognized by their peculiar garlic odor. In the open tube they give a white, volatile, crystalline sublimate of arsenious oxide. In the closed tube arsenic sulphide gives a sublimate dark brown-red when hot, and red or reddishyellow when cold. The presence of arsenic in minerals is often proved by testing them in the closed tube with sodium carbonate and potassium cyanide. Strong heating produces a sublimate of metallic arsenic, proper precautions being observed.

Baryta. B.B.; a yellowish-green coloration of the flame is given by all baryta salts, except the silicates.

In solution the presence of barium is proved by the heavy white precipi. tate formed upon the addition of dilnte sulphuric acid.

Bismuth. B.B. ; on charcoal alone, or with soda, bismuth gives a very characteristic orange-yellow sublimate (p. 207). Also when treated with equal parts of potassium iodide and sulphur, and fused on charcoal, a beautifrl red sublimate of bismuth iodide is obtained.

Boracic acid. Borates. B.B.; many compoundr tinge the flame intense yellowish-green, especially if moistened with sulphuric acid. For silicates
the best method is to mix the powdered mineral with one part powdered fluorite and two parts potassium bisulphate. The mixture is moistened and placed on platinum wire. At the moment of fusion the green color appears, but lasts but a moment (ex. tourmaline).

Heated in a dish with sulphuric acid, and alcohol being added and ignited, the flames of the latter will be distinctly tinged green.

Cudmium. B.B.; on charcoal cadmimn gives a characteristic sublimato of the reddish-brown oxide (p. 207)

C'arbonates. Effervesce with dilute hydrochloric acid; many require to be pulverized, and some need the addition of heat.

Chlorides. B.B. ; if a small portion of a chloride is added to the bead of salt of phosphorns, saturated with copper oxide, the bead is instantly surrounded with an inteuse purplish flane.

In solution they give with silver nitrate a white curdy precipitate, which darkens in color on exposure to the light; it is insoluble in nitric acid, but entirely so in ammonia.

Chromium. B.B. ; chrominm gives with borax and salt of phosphorus an emeraid-green bead (p. 208).

Cobalt. B.B.; a beautiful blue bead is obtained with borax in both flames from minerals containing cobalt. Where sulphur or arsenic is present it should first be roasted off on chareoal.

Copper. B.B.; on charcoal the metallic copper can be reduced from most of its compounds. With borax it gives a green bead in the oxidizing flame, and in the reducing an opaque red bead (p. 208).

Most metallic compounds are soluble in nitric acid. Ammonia produces a green precipitate in the solution, which is dissolved when an excess is added, the solution taking an intense blue color.

Fluorine. B.B. ; heated in the closed tube fluorides give off fumes of hydrofluoric acid, which react acid with test-paper and etch the glass. Sometines potassium bisulphate must be added (see also p. 207).

Heated gently in a platinum crucible with sulphuric acid, most compounds give off hydrofluoric acid, which corrodes a glass plate placed over it.

Iron. B.B.; with borax iron gives a bead (O.F.) which is yellow while hot, but is colorless on cooling ; R.F., becomes bottle-green (see p. 208). On charcoal with soda gives a magnetic powder. Minerals which contain even a small amount of iron yield a magnetic mass when heated in the reducing flame.

Leoul. B.B.; with soda on charcoal a malleable globule of metallic lead is obtained from lead compounds; the coating has a yellow color near the assay and farther off a white color (carbonate); on being touched with the reducing flame both of these disappear, tinging the flame azure blue.

In solutions dilute sulphuric acid gives a white precipitate of lead sulphate; when delicacy is required an excess of the acid is added, the solution evaporated to dryness, and water added, the lead sulphate, if present, will then be left as a residue.

Lime. B.B.; it imparts a yellowish-red color to the flame. In the pres. ence of other alkaline earths the spectroscope gives a sure means of detecting even when in small quantities. Many lime salts give an alkaline reaction with test-paper after ignition.

In solutions containing lime salts, even when dilute, ammonium oxalate throws down a white precipitate of calcium oxalate.

Lithia. B.B. ; lithia gives an intense red to the outer flame; in very small quantities it is evident in the spectroscope.

Magnesia. B.B. ; moistened, after heating, with cobalt nitrate and again ignited, a pink color is obtained from infusible minerals.

Manganese. B.B.; with borax manganese gives a bead violet-red (O.F.), and colorless (R.F.). Tith soda (O.F.) it gives a bluish-green bead ; this reaction is very delicate and may be relied upou, even in presence of almost any other metal.

Mercury. B.B.; in the closed tube a sublimate of metallie mercury is yielded when the mineral is heated with soda. Meren ic sulphide gives a black lustreless sublimate in the tube, red when rubbed (p 207).

Molybdenum. B.B.; on charcoal molybdenum gives a copper-red stain (O.F.) which becomes azure-blue when for a moment touched with the R.F. (p. 208).

Nicleel. B.B.; with borax nickel oxide gives a bead which (O.F.) is violet when hot and red-brown on cooling; (R.F.) the glass becomes gray and turbid from the separation of metallic nickel, and on long blowing colorless.

Nitrates. Detonate when heated on charcoal. Heated in a tube with sulphuric acid give off red fumes of nitric peroxide.

Phosphates. B.B.; most phosphates impart a green color to the flame, especially after having been moistened with sulphuric acid, thongh this test may be rendered unsatisfactory by the presence of other coloring agents. If they are used in the closed tube with a fragment of metallic magnesinm or sodium, and afterward moistened with water, phosphuretted hydrogen is given off, recognizable by its disagreeable odor.

A few drops of a neutral or acid solntion, containing phnsphoric acid, produces in a solution of ammonium molybdate with nitric ac"d a pulvernlent yellow precipitate.

Potash. B.B. ; potash imparts a violet color to the flame when alone. It is best detected in small quantities, or when soda or lithia is present, by the aid of the spectroscope.

Selenium. B.B.; on charcoal selenium fuses easily, giving off brown fumes with a peculiar disagreeable organic odor (see also p. 207).

Silica. B.B.; a small fragment of a silicate in the salt of phosphorus bead leaves a skeleton of silica, the bases being dissolved.

If a silicate in a fine powder is fused with sodium carbonate and the mass then dissolved in hydrochloric acid and evaporated to dryness, the silica is made insoluble, and when strong hydrochloric acid is added and then water, the bases are dissolved and the silica left behind.

Many silicates, especially those which are hydrons, are decomposed by strong hydrochloric acid, the silica separating as a powder or as a jelly (see p. 203).

Silver. B.B. ; on charcoal in O.F. silver gives a brown coating (p. 207). A globule of metallic silver may generally be obtained by heating on charcoal in O.F., especially if soda is added. Under some circumstances it is desirable to have recourse to cupellation.

From a solution containing any salt of silver, the insoluble chloride is thrown down when hydrochloric acid is added. This precipitate is insoluble

In acid or water, but entirely so in ammonia. It changes color on exposure to the light.

Sorla. B.B.; gives a strong yellow flame.
Sulphur, sulphides, sulphates. B.B.; in the closed tube some sulphides give off sulphur, others sulphurous oxide which reddens a strip of moistened litmus paper. In small quantities, or in sulphates, it is best detected by fusion on charcoal with soda. The fused mass, when sodium sulphide has thus been formed, is placed on a clean silver coin and moistened; a distinct black stain on the silver is thus obtained (the precaution mentioned on p. 209 must be exercised).

A solution in hydrochloric acid gives with barium chloride a white insoluble precipitate of barium sulphate.

Tellumium. B.B. ; tellurides heated in the open tube give a white or grayish sublimate, fusible to colorless drops (p. 207). On charcoal they give a white coating and color the R.F. green.

Tin. B.B; minerals containing tin, when heated on charcoal with soda or potassinm cyanide, yield metallic tin in minute globules (see also p. 209).

Titanium. B.B.; titanium gives a violet color to the salt of phosphorus bead. Fused with sodium carbonate and dissolved with hydrochloric acid, and heated with a piece of metallic tin or zinc, the liquid takes a violet color, especially after partial evaporation.

T'ungsten. B.B.; tungsten oxide gives a blue color to the salt of phosphorus head (R.F.). Fused and treated as titanic acid (see above) with the addition of zinc instead of tin, gives a fine blue color.

Uranium. B.B.; salt of phosphorus bead, in O.F., a greenish-yellow bead when cool. In R.F. a fine green on cooling (p. 209).

Vanudium. B.B.; the characteristic reactions of vanadium with the fluxes are given on p. 203.

Zinc. B.B. ; on charcoal compounds of zine give a coating which is yellow while hot and white on cooling, and moistened by the cobalt solution and again heated becomes a fine green (p. 207).

Zirconia. A dilute hydrochloric acid solution, containing zirconia, imparts an orange-yellow color to turmeric paper, moistened by the solution.

Students who desire to become thoronghly acquainted with the use of the blowpipe should provide themselves with a thorough and systematic book devoted to the subject. The most complete American book is that by Prof. Brash (Manual of Determinative Mineralogy, with an introduction on blowpipe analysis, New York, 1875). Other standard works are those of Ber. zelius (The nse of the Blowpipe in Chemistry and Mineralogy, translated into English by Prof. J. D. Whitney, 1845), and Plattner (Manual of Qualitative and Quantitative Analysis with the Blowpipe, translated by Prof. H. B. Cornwall, 1872). The work of Prof. Brush has been freely used in the preparation of the preceding notes upon blowpipe methods and reactions.

## Determinative Mineraloey.

Determinative Mineralogy may be properly considered under the general head of Chemical Mineralogy, since the determination of minerals depend
mostly upon chemical tests. But crystallographic and all physical characters liave also to be used.

There is but one satisfactory way in which the identity of an unknown mmeral may in all cases be fixed beyond question, and that is by the use of a complete set of determinative tables. By means of such tables the mineral in hand is referred successively from a general group into a more special one, until at last all other species have been eliminated, and the identity of the one given is beyond donbt.

A careful preliminary examination of the unknown mineral shonld, how. ever, always be made before final recourse is had to the tables. This examination will often suffice to show what the mineral in hand is, and in any case it should not be omitted, since it is only in this way that a practical faniliarity with the appearance and characters of minerals can be gained.

The student will naturally take note first of those characters which are at once obvious to the senses, that is: the color, lustre, feel, general struc ture, fracture, cleavage, and also crystalline form, if distinct ; also, if the specimen is not too small, the apparent weight will suggest something as to the specific gruvity. The above characters are of very unequal importance. Strincture, if cerystals are not present, and fracture are generally unessential except in distinguishing varieties; color and lustre are essential with metallic, but generally rery mimportant with mmetallic minerals. Streak is of importance only with colored minerals and those of metallic lustre (p. 162). Crystalline form and cleavage are of the highest importance, but usually require careful study.

The first trial should be the determination of the hardness (for which end the pocket-knife is often sufficient in experienced hands). The second trial should be the determination of the specific gravity. Treatment of the powdered mineral with acids may come next; by this means (see p. 202) the presence of carbonic acid is detected, and also other results obtained (p. 203). Then should follow blowpipe trials, to ascertain the fusibility, the color given to the flame, if any, the character of the sublimate given off and the reactions with the fluxes and other points as explained in the pre ceding pages.

How much the observer learns in the above way, in regard to the nature of his mineral, depends upon his knowledge of the characters of minerals in general, and upon his familiarity with the chemical behavior of the varioas elementary snbstances (p. 210 to \%13) with reagents, and before the blowpipe. If the results of such a preliminary examination are sufficiently definite to suggest that the mineral in hand is one of a small number of species, reference may be made to their full description in Part III. of this work for the final decision.

A number of minor tables, embracing under appropriate heads minerals which have some striking physical characters, are added in the Appendix. They will in many cases aid the observer in reaching a conclusion. In addition to these tables, an extended table is also given fur the systematic determination of the more important minerals, those described in full in the following pages.

## PARTIII.*

## DESCRIPTIVE MINERALO(̛YY.

The following is the system of classification employed in the arrangement of the species in this work. It is identical with that adopted in Dana's System of Mineralogy, 1863, to which treatise reference may be made for the discussion of the principles upon which it is based. In general only the more prominent species are enumerated under the successive heads.

The native elements are grouped as follows:
SERIES I.-The more basic, or electro-positive elements.

1. Gold grour.-Gold, silver (also hydrogen, potassium, sodium, etc.).
2. Iron group.-Platinum, palladium, mercury, copper, iron, zinc, lead (also cobalt, nickel, chromium, manganese, calcium, magnesium, etc.).
3. Tin grour.-Tin (also titanium, zirconium, etc.).

SERIES II.-Elements generally electro-negative.

1. Arsenio group.-Arsenic, antimony, bismuth, phosphorus, vanadium, etc.
2. Sulphur group.-Sulphur, tellurium, selenium.
3. Carbon-sllicon group.-Carbon, silicon.

SERIES III.-Elements always negative.

1. Chlorine, bromine, iodine.
2. Fluorine.
3. Oxygen.

## CLASSIFICATION OF MINERAL SPECIES.

## I. NATIVE ELEMENTS.

Gold ; silver.-Platinum ; palladium ; iridosmine, IrOs, etc.; xercury ; amalgam, AgHg , etc. ; copper; iron.-Arsenic ; antimony; bismuth.-. Tellurium; sulphur.-Diamond; graphite.

## II. SULPHIDES, TELLURIDES, SELENIIES, ARSENIDES, ANTLMONIDES, BISMUTHIDES.

1 BINARY COMPOUNDS.-Sulphides and Tellurides of Merals uf the Sulphur and Arsenic Groups.
(a) Realgar group. Composition RS. Monoclinic. Realgar.
(b) Orpiment group. Composition $\mathrm{R}_{2} \mathrm{~S}_{3}$. Orthorhombic. Orpiment; stibnite; bismuthinite.
(c) Tetradymite group. Tetradymite $\mathrm{Bi}_{2}(\mathrm{Te}, \mathrm{S})_{3}$.
(d) Molybdenite group. Composition $\mathrm{RS}_{2}$. Molybdenite.
2. Binary Compounds.-Sulphides, Tellurides, etc., of Metale of the Gold, Iron, and Tin Groups.
A. BASIC DIVISION.-Dyscrasite ; domeykite.
B. PROTO DIVISION:-Composition RS (or $\mathrm{R}_{2}^{\mathrm{R}} \mathrm{S}$ ), RSe, RTe.
(a) Galenite group. Isometric; holohedral.—Argentite; galenite; clansthalite; bornite; alabandite.
(b) Blende group. Isometric ; tetrahedral.-Sphalerite.
(c) Chalcocite group. Orthorhombic.-Chalcocite; acanthite; hessite ; stromeyerite.
(d) Pyrrhotite group. Hexagonal.-Cinnabar; millerite; pyrrhotite ( $\mathrm{Fe}_{7} \mathrm{~S}_{8}^{2}$ ) ; greenockite ; niccolite.
C. DEUTO or PYRITE DIVISION.-Composition $\mathrm{RS}_{2}$, ets.
(a) Pyrite group. Isometric.-Pyrite; linnæite; smaltite; cobaltite ; gersdorffite.-Chalcopyrite.
(b) Marcasite group. Orthorhombic.-Marcasite; arsenopyrite; sylvanite.
(c) Nagyagite. (d) Covellite.
3. TERNARY COMPOUNDS.-Sulpharsenttes, Sulphantimonttes, Sulphobismuthites.
(a) Group I. Atomic ratio, $\mathrm{R}: \mathrm{As}(\mathrm{Sb}): \mathrm{S}=1: 2: 4$. Formula $\mathrm{R}(\mathrm{As}, \mathrm{Sb})_{2} \mathrm{~S}_{4}=\mathrm{RS}+(\mathrm{As}, \mathrm{Sb})_{2} \mathrm{~S}_{3}$. Miargyrite ; sartorite ; zinkenite.
(b) Sub group. At. Ratio, $\mathrm{R}: \mathrm{As}(\mathrm{Sb}): \mathrm{S}=3: 4: 9$. Formula $\mathrm{R}_{3}(\mathrm{As}, \mathrm{Sb}, \mathrm{Bi})_{4} \mathrm{~S}_{9}=3 \mathrm{RS}+2(\mathrm{As}, \mathrm{Sb}, \mathrm{Bi})_{2} \mathrm{~S}_{8} . \quad$ Jordanite $;$ schirmerite, etc.
(c) Group II. At. Ratio, R : (As, Sb ) : $\mathrm{S}=2: 2: 5$. Formula $\mathrm{R}_{2}(\mathrm{Sb}, \mathrm{As})_{2} \mathrm{~S}_{5}=2 \mathrm{RS}+(\mathrm{Sb}, \mathrm{As})_{2} \mathrm{~S}_{3}$. Jamesonite ; dufrenoysite.
(i) Group III. At. Ratio, $\mathrm{R}:(\mathrm{As}, \mathrm{Sb}): \mathrm{S}=3: 2: 6$. Formula $\mathrm{R}_{3}(\mathrm{As}, \mathrm{Sb})_{2} \mathrm{~S}_{6}=3 \mathrm{RS}+(\mathrm{As}, \mathrm{Sb})_{2} \mathrm{~S}_{3} . \quad$ Pyrargyrite, proustite; bournonite; boulangerite.
(e) Grour IV. At. Ratio, $\mathrm{R}:(\mathrm{As}, \mathrm{Sb}, \mathrm{Bi}): \mathrm{S}=4: 2: 7$. Formula $\mathrm{R}_{4}(\mathrm{As}, \mathrm{Sb}, \mathrm{Bi})_{2} \mathrm{~S}_{7}=4 \mathrm{RS}+(\mathrm{As}, \mathrm{Sb}, \mathrm{Bi})_{2} \mathrm{~S}_{3}$. Tetrahedrite; tennantite.
( $f$ ) Group V. At. ${ }^{\circ}$ Ratio, $\mathrm{R}:(\mathrm{As}, \mathrm{Sb}): \mathrm{S}=5: 2: 8$. Formula $R_{5}(\mathrm{As}, \mathrm{Sb})_{2} \mathrm{~S}_{8}=5 \mathrm{RS}+(\mathrm{As}, \mathrm{Sb})_{2} \mathrm{~S}_{3}$. Stephanite; geocronite P olybasite.-Enargite.

## III. CHLORIDES, BROMIDES, IODIDES.

1. ANHYDROUS CHLORIDES.-Composition mostly $\mathrm{R}(\mathrm{Cl}, \mathrm{Br}, \mathrm{I})$; also $\mathrm{R}_{2}(\mathrm{Cl}, \mathrm{Br}, \mathrm{I})$ (calomel), and $\mathrm{ZCl}_{6}$ (molysite).

Halite; sylvite ; cerargyrite; embolite ; bromyrite.
2. IIYDROUS CHLORIDES.-Carnallite. Tachhydrite.
3. OXYCHLORIDES-Atacamite: matlockite.

## IV. FLUORIDES.

1. ANHYDROUS FLUORIDES. Fluorite; sellaite.-Cryolite.
2. HYDROUS FLUORIDES.-Pachnolite; ralstonite.

## V. OXYGEN COMPOUNDS.

## I. OXIDES.

1. OXIDES of Metals of the Gold, Iron, and Tin Groups.
A. ANHYDROUS OXIDES.-(a) Protoxides.-Binary compounds of oxygen with a univalent or bivalent element. Formula RO or $\left(\mathrm{R}_{2} \mathrm{O}\right)$. Cuprite; zincite ; tenorite.
(b) Sesquioxines.-Binary compounds of oxygen with a sexivalent element. Formnla $\mathbb{R O}_{3}$. Corundum; hematite. This group also includes menaccanite and perofskite.
(c) Compounds of Protoxides and Sesquioxides.-Ternary compounds of oxygen with a bivalent and a sexivalent element. Formula RI()$_{4}=\mathrm{RO}$ $+\mathrm{ZO}_{3}$.
Spinel Group. Isometric.-Spinel ; gahnite; magnetite; franklinite; chromite, Orthorhombic.-Chrysoberyl.
(d) Deuroxides.-Binary compounds of oxygen with a quadrivalent element. Forinula $\mathrm{RO}_{2}$.

Tetragonal.-Rutile Group.-Cassiterite ; rutile ; octakedrite; hausmannite ; bramnite. Orthorhombic.-Brookite; pyrolusite.
B. IIYDROUS OXIDES.-Turgite.-Diaspore ; göthite ; manganite.-Limonite.-Brucite ; gibbsite.-Psilomelane.
2. OXIDES of Metals of the Arsenio and Sulphur Grocps.

Isometric.-Arsenolite; senarmontite. Orthorhombic. - Claudetite; valentinite ; bismite, etc.
3. OXIDES of the Carbon-sllicon Group.-Quartz; tridymite; asmanite; opal.

## II. TERNARY OXYGEN COMPOUNDS.

## 1. SiliCates.-A. Anhydrous Silicates.

(a) Bisilicates.-Salts of meta-silicic acid, $\mathrm{H}_{2} \mathrm{SiO}_{3}$. Quantivalent ratio for basic elements and silicon, $1: 2$. General formula $\mathrm{RSiO}_{3}$. This may be written: $\mathrm{R}\left\|\mathrm{O}_{2}\right\| \mathrm{SiO}$, to indicate that part only of the oxygen is regarded as linking oxygen, or, taking into account the quantivalence of the various basic elements that may be present, $\mathrm{R}_{2}, a \mathrm{R}, \beta \mathrm{R}\left\|\mathrm{O}_{2}\right\| \mathrm{SiO}$.
(a) Amphibole group. I'yroxene section ( $I \wedge I=86^{\circ}-88^{\circ}$ ). Orthorhom. bic.-Enstatite ; hypersthene. Monoclinic. - Wollastonite; pyroxene ; acmite; ægirite. Triclinic.-Rhodonite; babingtonite.-Spodumene; petalite.
(b) Amphibole section $\left(I \wedge I=123^{\circ}-125^{\circ}\right)$. Orthorhombic.-Anthophyllite, kupfferite. Monoclinic, amphibole; arfvedsonite.

Beryl. Eudialyte. Pollucite.
( $\beta$ ) Unisilicates.-Salts of the normal silicic acid, $\mathrm{H}_{4} \mathrm{SiO}_{4}$. Quantivalent ratio for basic elements and silicon, 1:1. General formula $\mathrm{R}_{2} \mathrm{SiO}_{4}$. This may be written: $R_{2}\left\|O_{4}\right\| \mathrm{Si}$, to show that all the oxygen is regarded as linking oxygen, or, $\mathrm{R}_{2}, a \mathrm{R}, \beta \mathrm{R}\left\|\mathrm{O}_{4}\right\| \mathrm{Si}$. The latter formula shows that, though elements of different quantivalence may be present, the same unisilicate type still exists. The excess of silica sometimes present in both bisilicates and misilicates, as well as other deviations from the ordinary types, are remarked upon in the pages which follow.
(a) Chrysolite group. Orthorhombic, $I \wedge I=91^{\circ}-95^{\circ} ; O \wedge 1-\bar{\imath}=124^{\circ}-$ $129^{\circ}$.-Chrysolite, forsterite, tephroite, monticellite, etc.
(b) Willemite group. Hexagonal, $\mathrm{R} \wedge \mathrm{R}=116^{\circ}-117^{\circ}$.-Willemite, dioptase, phenacite.
(c) Isometric. Helvite. Danalite, $\mathrm{R}_{2} \mathrm{SiO}_{4}+\mathrm{RS}$.
(d) Garnet group. Isometric.-Q. ratio for $\mathrm{R}: \mathbb{R}: \mathrm{Si}=1: 1: 2$. General formula $\mathrm{R}_{3} \mathrm{PSSi}_{3} \mathrm{O}_{12}$.
(e) Vesuvianite group. Tetragonal.-Zircon, vesuvianite.
( $f$ ) Epidote group. Anisometric.-Epidote; allanite; zoisite ; gadolinite ; ilvaite.
(g) Triclinic. Axinite. Danburite.-(h) Iolite.
(\%) Mica group. $I \wedge I=120^{\circ}$. Cleavage basal perfect; optic axis or acute bisectrix normal to the cleavage-plane.-Phlogopite; biotite; lepido melane ; muscovite; lepidolite.
(l) Scapolite group. Tetragonal.-Sarcolite; meionite; wernerite; ekebergite.
$(m)$ Hexagonal. Nephelite. Isometric.-Sodalite ; haüynite ; nosite; leucite.

Feldspar group. Monoclinic or triclinic. $I \wedge I$ near $120^{\circ}$; Q. raiio for $\mathrm{R}: \mathrm{R}=1: 3$. Anorthite; labradorite; andesite; hyalophane; oligoclase ; albite ; orthoclase (microcline).
(y) Subililcates.-(a) Q. ratio for bases to silicon, 4:3. Chondrodite T'ourmaline.
(b) Q. ratio for bases to silicon, 3:2. Gehlenite.-Andalusite; fibrolite; eyanite ( $\pm 1 \mathrm{SiO}_{6}$ ).-Topaz; euclase; datolite.-Guarinite ; titanite ; keilhauite ; tschefflkinite.
(c) Q. ratio for bases to silicon, $2: 1$. Staurolite.

## B. Hydrous Silicates-General Section.

Bisilicates.-Pectolite ; laumontite ; okenite.-Chrysocolla ; alipite, etc.
Unisilicates.-Calamine; prehnite.-Thorite. Pyrosmalite.-Apophyllite.

Subsllicates.-Allophane.

## Zeolite Section.

Thomsonite ; natrolite ; scolecite ; mesolite.-Levynite.-Analcite.Chabazite; gmelinite; herschelite.-Phillipsite.-Harmotome.-Stilbite; heulandite.

## Margarophyllite Section.

Brilicates.-Talc. Pyrophyllite.-Sepiolite; glauconite.
Unishlicates.-Serpentine group. Serpentine; deweylite; genthite.
Kaolinite group. Kaolinite; pholerite; halloysite.
Pinite group. Pinite, etc.; palagonite.
Hydro-mica group. Fahlunite; margarodite; damourite; paragonite; cookeite.-Hisingerite.

C'hlorite group. Vermiculites, Q. ratio of bases to silicon, 1:1. Pyrosclerite; jefferisite, etc.-Penninite.-Ripidolite ; prochlorite.-Chloritoid; margarite. Seybertite.

## 2. TANTALATES, COLUMBATES.

Pyrochlore.-Tautalite ; columbite; yttrotantalite; samarskite; euxenite ; æschynite, etc.

## 3. PHOSPHATES, ARSENATES, VANADATES.

Aniyndous.-Xenotime $\mathrm{Y}_{3} \mathrm{P}_{2} \mathrm{O}_{8}$; pucherite.--Descloizite.
Hexagonal.-Formula $3 \mathrm{R}_{3}\left(\mathrm{P}, \mathrm{As}, \mathrm{V}_{2} \mathrm{O}_{8}+\mathrm{R}(\mathrm{Cl}, \mathrm{F})_{2}\right.$. Apatite ; pyromor phite; mimetite; vanadinite.

Wagnerite ; monazite.-Triphylite ; triplite.-Amblygcnite (hebronite)

Hydrous.-Pharmacolite; brushite.-Vivianite ; erythrite.-Libethinite; olivenite.-Liroconite ; pseudomalachite.-Clinoclasite.-Lazulite; scorodite; wavellite; pharmacosiderite.-Childrenite.-Turquois; cacoxenite. -Torbernite ; autunite.

Hydrous antimonate.-Bindheimite.

## 4. BORATES.

Sassolite ; sussexite ; ludwigite.-Boracite ; ulexite; priceite.-Warwickite.
5. TUNGSTATES, general formula RWO $_{4}$; MOLYBDATES, $\mathrm{RMoO}_{4}$; CHROMATES, $\mathrm{RCrO}_{4}$.

Wolframite; scheelite; stolzite.-Wulfenite.-Crocoite; phœnicochroite.

## 6. SULPHATES.

Anhydrous.-General formula $\mathrm{RSO}_{4}$. Orthorhombic $I \wedge I=100^{\circ}-105^{\circ}$.
-Barite; celestite; anhydrite; anglesite; zinkosite ; leadhillite.
Caledonite--Dreelite ; susannite ; connellite.-Glauberite ; lanarkite. Hydrous sulphates.-Mirabilite.-Gypsum.-Polyhalite.-Epsomite.
Copperas group. Chalcanthite, $\mathrm{CuSO}_{4}+5 \mathrm{aq}$, also the other vitriols, $\mathrm{RSO}_{4}+7 \mathrm{aq}$.

Copiapite.-Aluminite.-Linarite; brochantite, etc.
Tellurates.-Montanite, $\mathrm{Bi}_{2} \mathrm{TeO}_{6}+2 \mathrm{aq}$.

## 7. CARBONATES.

Anhydrous.-Calcite group. Rhombohedral. General formula, $\mathrm{RCO}_{3}$. -Calcite; dolomite; magnesite; siderite; rhodochrosite; smithsonite.

Aragonite group. Orthorhombic.-Aragonite ; witherite ; strontianite ; cerussite ; baryto-calcite.-Phosgenite.

Hydrous oarbonates.-Gaylussite,-Hydromagnesite.-Hydrozincite ; malachite; azurite.--Bismutite, etc.

## VI. HYDROCARBON COMPOUNDS.

## 1. NATIVE ELEMENTS.

## GOLD. $X$

Iscmetric. The octahedron and dodecahedron the most commen forms Crystals sometimes acicular through elongation of octahedral or other forms ; also passing into filiform, reticulated, and arborescent shapes; and occasionally spongiform from an aggregation of filaments; edges of crystals often salient (f. 415). Cleavage none. Twins: twinning-plane octahedral. Also massive and in thin laminæ. Often in flattened grains or scales, and rolled masses in sand or gravel.
H. $=2 \cdot 5-3 . \quad$ G. $=15 \cdot 6-19 \cdot 5 ; 19 \cdot 30-19 \cdot 34$, when quite pure, G. Rose. Lustre metallic. Color and streak
 various shades of gold-yellow, sometimes inclining to silver-white. Very ductile and malleable.

Composition, Varieties.-Gold, but containing silver in different proportions, and sometimesalso traces of copper, iron, bismuth (maldonite), palladiun, rhodium. Var. 1. Ordinary. Containing 0.16 to 16 p . c. of silver. Color varying, accordingly, from deep gold-yellow to pale yellow ; G. $=19-15^{\circ} 5$. 2. Argentiferous; E'lectrum. Color pale yellow to yellowish white; G. $=15 \cdot 5-12 \cdot 5$. Ratio for the gold and silver of $1: 1$ corresponds to 35.5 p . c. of silver, $2: 1$, to 21.6 p. c.

The average proportion of gold in the native gold of California, as derived from assays of several hundred millions of dollars' worth, is 880 thousandths; while the range is mostly between 870 and 890 (Prof. J. C. Booth, of U. S. Mint). The range in the metal of Australia is mostly between 900 and 960 , with an average of 925 . The gold of the Chaudière, Canada, contains usually 10 to 15 p c. of silver; while that of Nova Scotia is very nearly pure. The Chilian gold afforded Domeyko 84 to 96 per cent. of gold and 15 to 3 per cent. of silver. (Ann. d. Mines, IV. vi.)

Pyrognostic and other Chemical Characters.-B.B.fuses easily. Not acted on by fluxes. Insoluble in any single acid; soluble in nitro-hydrochloric acid (aqua-regia).
D.ff-Readily recognized by its malleability and specific gravity. Distinguished by its insolubility ia nitric acid from pyrite and chalcopyrite.

Observations.-Native gold is found, when in situ, with comparatively small exceptions, in the quartz veins that intersect metamorphic rocks, and to some extent in the wall rock of these veins. The metamorphic rocks thus intersected are mostly chloritic, talcose, and argillaceous schist of dull green, dark gray, and other colors ; also, much less commonly, mica and hornblendic schist, gneiss, dioryte, porphyry ; and still more rarely, granite. A laminated quartzyte, called itacolumyte, is common in many gold regions, as those of Brazil and North Carolina, and sometimes specular schists, or slaty rocks containing much foliated specular iron (hematite), or magnetite in grains.

The gold occurs in the quartz in strings, scales, plates, and in masses which are sometimes an agglomeration of crystals; and the scales are often invisible to the naked eye, massiva quartz that apparently contains no gold frequently yielding a considerable percentage to the assayer. It is always very irregularly distributed, and never in continuous pure bands of metal, like many metallic ores. It occurs both disseminated through the mass of the quartz, and in its cavities. The associated minerals are : pyrite, which far exceeds in quantity all others, and is generally auriferous; next, chalcopyrite, galenite, sphalerite, arsenopyrite, each frequently auriferous; often tetradymite and other tellurium ores, native bismuth, stibnite, magnetite, hematite; sometimes barite, apatite, fluorite, siderite, chrysocolla.

The gold of the world has been mostly gathered, not directly from the quartz veins, but
from the gravel or sands of rivers or valleys in auriferous regions, or the slopes of mountains or hills, whose rocks contain in some part, and generally not far distant, auriferous veins, such mines are often called alluvial roashings; in California placer-diggings. Most of the gold of the Urals, Brazil, Australia, and all other gold regions, has come from such alluvial washings. The alluvial gold is usually in flattened scales of different degrees of fineness, the size depending partly on the original condition in the quartz veins, and partly on the distance to which it has been transported. Transportation by running water is an assort ng process; the coarser particles or largest pieces requiring rapid currents to transport them, and dropping first, and the finer being carried far away-sometimes scores of miles. A cavity in the rocky slopes or bottom of a valley, or a place where the waters may have eddied, generally proves in such a region to be a pocket full of gold.

In the auriferous sands, crystals of zircon are very common; also garnet and cyanite in grains; often also monazite, diamonds, topaz, magnetite, corundum, iridosmine, platinum. The zircons are sometimes mistaken for diamonds.

Gold exists more or less abundantly over all the continents in most of the regions of crystalline rocks, especially those of the semi-crystalline schists; and also in some of the large islands of the world where such rocks exist. In Europe, it is most abundant in Hungary and in Transylvania; it occurs also in the sands of the Rhine, the Reuss, the Aar, the Rhone, and the Danube; on the southern slope of the Pennine Alps, from the Simplon and Monte Rosa to the valley of Aosta; in Piedmont; in Spain, formerly worked in Asturias; in many of the streams of Cornwall; near Dolgelly and other parts of North Wales; in Scotland; in the county of Wicklow, Ireland ; in Sweden, at Edelfors.

In Asia, gold occurs along the eastern flanks of the Urals for 500 miles, and is especially abundant at the Beresov mines near Katharinenburg (lat. $56^{\circ} 40^{\prime} \mathrm{N}$.) ; also obtained at Petropavlovski ( $60^{\circ} \mathrm{N}$.) ; Nischne Tagilsk ( $59^{\circ} \mathrm{N}$.) ; Miask, near Slatoust and Mt. Ilmen ( $\check{5} \tilde{5}^{\circ} \mathrm{N}$., where the largest Russian nugget was found), etc. Asiatic mines occur also in the Cailas Mountains, in Little Thibet, Ceylon, and Malacca, China, Corea, Japan, Formosa, Sumatra, Java, Borneo, the Philippines, and other East India Islands.

In Africa, gold occurs at Kordofan, between Darfour and Abyssinia; also, south of the Sahara in Western Africa, from the Senegal to Cape Palmas; in the interior, on the Somat, a day's journey from Cassen ; along the coast opposite Madagascar, between $22^{\circ}$ and $35^{\circ} \mathrm{S}$., supposed by some to have been the Ophir of the time of Solomon.

In South America, gold is found in Brazil; in New Granada; Chili; in Bolivia; sparingly in Peru. Also in Central America, in Honduras, San Salvador, Guatemala, Costa Rica, and near Panama; most abundant in Honduras.

In North America, there are numberless mines along the mountains of Western America, and others along the eastern range of the Appalachians from Alabama and Georgia to Labrador, besides some indications of gold in portions of the intermediate Archean region about Lake Superior. They occur at many points along the higher regions of the Rocky Mountains, in Mexico, and in New Mexico, in Arizona, in the San Francisco, Wauba, Yuma, and other districts ; in Colorado, abundant, but the gold largely in auriferous pyrite ; in Utah, and Idaho, and Montana. Also along ranges between the summit and the Sierra Nevada, in the Humboldt region and elsewhere. Also in the Sierra Nevada, mostly on its western slope (the mines of the eastern being principally silver mines). The auriferous belt may be said to begin in the Californian peninsula. Near the Tejon pass it enters California, and beyond for 180 miles it is sparingly auriferous, the slate rocks being of small breadth; but beyond this, northward, the slates increase in extent, and the mines in number and productiveness, and they continue thus for 200 miles or more. Gold occurs also in the Coast ranges in many localities, but mostly in too small quantities to be profitably worked. The regions to the north in Oregon and Washington Territory, and the British Possessions farther north, as also our possessions in Alaska, are at many points auriferous, and productively so, though to a less extent than California.

In eastern North America, the mines of the Southern United States produced before the California discoveries, in 1849, about a million of dollars a year. They are mostly confined to the States of Virginia, North and South Carolina, and Georgia, or along a line from the Rappahannock to the Coosa in Alabama. But the region may be said to extend north to Canada; for gold has been found at Albion and Madrid in Maine; Canaan and Lisbon, N. H. ; Rridgewater, Vermont; Dedham, Mass Traces occur also in Franconia township, Montgomery Co., Pennsylvania. In Canada, gold occurs to the south of the St. Lawrence, in the soil on the Chaudiàre, and over a considerable region beyond. In Nova Scotia, mines are tworked near Halifax and elsewhere.

In Australia, which is fully equal to California in productiveness, and nuach superior in the purity of the metal, the principal gold mines occur along the streams in the mountains of N. S. Wales (S. E. Australia), and along the continuation of the same range in Victoria (S. Australia).
$+$

## SILVER.

Isometric. Cleavage none. Twins: twinning-plane octahedral. Commonly coarse or fine filiform, reticulated, arborescent; in the latter, the branches pass off either (1) at right angles, and are crystals (usually octahedrons) elongated in the direction of a cubic axis, or else a succession of partly overlapping crystals; or (2) at angles of $60^{\circ}$, they being elongated in the direction of a dodecahedral axis. Crystals generally obliquely prolonged or shortened, and thus greatly distorted. Also massive, and in plates or superficial coatings.
$\mathrm{H} .=2 \cdot 5-3$. G. $=10 \cdot 1-11 \cdot 1$, when pure $10 \cdot$. . Lustre metallic. Color and streak silver-white; subject to tarnish, by which the color becomes grayish-black. Ductile.

Comp., Var.-Silver, with some copper, gold, and sometimes platinum, antimony, bismuth, mercury.

Ordinary. ( $a$ ) crystallized; (b) filiform, arborescent; (c) massive. Auriferous. Contains 10 to 30 p . c. of gold ; color white to pale brass-yellow. There is a gradual passage to argentiferous gold. Cupriferous. Contains sometimes 10 p. c. of copper.

Pyr., etc.-B.B. on charcoal fuses easily to a silver-white globule, which in O.F. gives a faint dark-red coating of the oxide ; crystallizes on cooling. Soluble in nitric acid, and deposited again by a plate of copper.

Obs.-Native silver occurs in masses, or in arborescent and filiform shapes, in veins traversing gneiss, schist, porphyry, and other rocks. Also occurs disseminated, but usually invisibly, in native copper, galenite, chalcocite, etc.

The mines of Kongsberg, in Norway, have afforded magnificent specimens of native silver. The principal Saxon localities are at Freiberg, Schneeverg, and Johanngeorgenstadt; the Bohemian, at Przibram, and Joachimsthal. It also occurs in small quantities with other ores, at Andreasberg, in the Harz; in Suabia; Hungary; at Allemont in Dauphiny; in the Ural near Beresof; in the Altai, at Zméoff ; and in some of the Cornish mines.
Mexico and Peru have been the most productive countries in silver. In Mexico it has been obtained mostly from its ores, while in Peru it occurs principally native. In Durango, Sinaloa, and Sonora, in Northern Mexico, are noted mines affording native silver.

In the United States it is disseminated through much of the copper of Michigan, occasionally in spots of some size, and sometimes in cubes, skeleton octahedrons, etc., at various mines. In Idaho, at the "Poor Man's lode," large masses of native silver have been obtained. In Nevada, in the Comstock lode, it is rare, and mostly in filaments; at the Ophir mine rare, and disseminated or filamentous; in California, sparingly, in Silver Mountain district, Alpine Co. ; in the Maris vein, in Los Angeles Co. ; in the township of Ascot, Canada.

## platinum. $X$

Isometric. Rarely in cubes or octahedrons. Usually in grains; nccasionally in irregular lumps, rarely of large size. Cleavage none. $\mathrm{H} .=4-4 \cdot 5 . \quad$ G. $=16-19 ; 17 \cdot 108$, small grains, $17 \cdot 608$, a mass, Breith. Lustre metallic. Color and streak whitish steel-gray; shining. Opaque. Ductile. Fracture hackly. Occasionally magneti-polar.

Comp.-Platinum combined with iron, iridium, osmium, and other metals. The amount of iron varies from 4-20 p. c.

Pyr., etc.-Infusible. Not affected by borax or salt of phosphorus, except in the state of fine dust, when reactions for iron and copper may be obtained. Soluble only in heated nitrohydronhlorio aoid.

Diff-Distinguished by its malleability, high specific gravity, infusibility, and entire insol ability in the ordinary acids.

Obs.-Platinum was first found in pebbles and small grains in the alluvial deposits of the river Pinto, in the district of Choco, near Popayan, in South America, where it received its name platina, from plata, silver. In the province of Antioquia, in Brazil, it has been found in auriferous regions in syenite (Boussingault).

In Russia, it occurs at Nischne Tagilsk, and Goroblagodat, in the Ural, in alluvial material. Formerly used as coins by the Russians. Russia affords annually about 800 cwt. of platinum, which is nearly ten times the amount from Brazil, Columbia, St. Domingo, and Borneo. Platinum is also found on Borneo; in the sands of the Rhine; at St. Aray, val du Drac; county of Wicklow, Ireland; on the river Jocky, St. Domingo ; in California, but not abundant : in traces with gold in Rutherford Co., North Carolina; at St. Francois Beauce, etc., Canada East.

Platiniridium.-Platinum and iridium in different proportions. Urals; Brazil.

## PALLADIUM.

Isometric. In minute octahedrons, Haid. Mostly in grains, sometimes composed of diverging fibres.
H. $=4 \cdot 5-5$. G. $=11 \cdot 3-11 \cdot 8$, Wollaston. Lustre metallic. Color whitish steel-gray. Opaque. Ductile and malleable.

Comp.-Palladium, alloyed with a little platinum and iridium, but not yet analyzed.
Obs.-Palládium occurs with platinum, in Brazil, where quite large masses of the metal are sometimes met with; also reported from St. Domingo, and the Ural.

Palladium has been employed for balances ; also for the divided scales of delicate apparatus, for which it is adapted, because of its not blackening from sulphur gases, while at the same time it is nearly as white as silver.

## IRIDOSMINE. Osmiridium.

Hexagonal. Rarely in hexagonal prisms with replaced basal edges. Commonly in irregular flattened grains.
H. $=6-7$. G. $=19 \cdot 3-21 \cdot 12$. Lustre metallic. Color tin-white, and light steel-gray. Opaque. Malleable with difficulty.

Comp., Var.-Iridium and osmium in different proportions. Two varieties depending on these proportions have been named as species, but they are isomorphous, as are the metals (G. Rose). Some rhodium, platinum, ruthenium, and other metals are usually present.

Var. 1. Nerojanskite, Haid.; H. $=7$; $\mathrm{G}_{\mathrm{F}}=18 \cdot 8-19 \cdot 5$. In flat scales; color tin-white. Over 40 p. c. of Iridium. Probably IrOs.
2. Sisserskite, Haid. In flat scales, often six-sided, color grayish-white, steel-gray. G. $=$ 20-212. Not over 30 p . c of iridium. One kind from Nischne Tagilsk afforded Berzelus IrOs ${ }_{4}=$ Iridium $19 \cdot 9$, osmium $80 \cdot 1=100$; G. $=21 \cdot 118$. Another corresponded to the formula IrOss.

Pyr, etc.-At a high temperature the sisserskite gives out osmium, but undergoes no further change. The newjanskite is not decomposed and does not give an osmium odor until fused with nitre.

Diff.-Distinguished from platinum by its superior hardness.
Obs.-Occurs with platinum in the province of Choco in South America; in the Ural mountains; in Australia. It is rather abundant in the auriferous beach sands of northern California, occurring in small bright lead-colored scales, sometimes six-sided. Also traces in tha gold-washings on the rivers du Loup and des Plantes, Canada.


MERCURY. Quicksilver. Gediegen Quecksilber, Germ.
Isometric. Occurs in small fluid globules scattered through its gangue G. $=13.568$. Lustre metallic. Color tin-white. Opaque.

Comp.-Pure mercury (Hg) ; with sometimes a little silver.
Pyr., etc.-B.B., entirely volatile. Dissolves readily in nitric acid.
Obs.-Mercury in the metallic state is a rare mineral ; the quicksilver of commerce is obtained mostly from cinnabar, one of its ores. The rocks affording the metal and its ores are mostly clay shales or schists of different geological ages.

Its most important mines are those of Idria in Carniola, and Almaden in Spain. It is found in small quantities in Carinthia, Hungary, Pcru, and other countries; in California, especially in the Pioneer mine, in the Napa Valley.

## AIMALGAIM.

Isometric. The dodecahedron a common form, also the cube and octa hedron in combination (see f. 40, 41, etc., p. 15). Cleavage : dodecahedral in traces. Also massive.
$\mathrm{H} .=3-3.5$. G. $=13.75-14$. Color and streak silver-white. Opaque. Fracture conchoidal, uneven. Brittle, and giving a grating noise when cut with a knife.

Comp.-Both Ag Hg (=Silver $35 \cdot 1$, mercury, 64.9), and $\mathrm{Ag}_{2} \mathrm{Hg}_{3}$ (=Silver 26.5, and mercury, $73 \cdot 5$ ), are here included.

Pyr., etc,-B.B., on charcoal the mercury volatilizes and a globule of silver is left. In the closed tube the mercury sublimes and condenses on the cold part of the tube in minute globules. Dissolves in nitric acid.

Obs.-From the Palatinate at Moschellandsberg. Also reported from Rosenau in Hungary, Sala in Sweden, Allemont in Dauphiné, Almaden in Spain.

Arquerite.-Composition $\mathrm{Ag}_{12} \mathrm{Hg}=$ silvêr $86 \cdot 6$, mercury, $13 \cdot 4=100$. Chili. Konasbergite, $\mathrm{Ag}_{18} \mathrm{Hg}$ (?) Kongsberg, Norway.

## COPPER.

Isometric. Cleavage none. Twins: twinning-plane octahedral, very common. Often filiform and arborescent; the latter with the bra!ches passing off usually at $60^{\circ}$, the supplement of the dodecahedral angle. Also massive.
H. $=2 \cdot 5-3 . \quad$ G. $=8 \cdot 838$, Whitney. Lustre metallic. Color copper-red. Streak metallic shining. Ductile and malleable. Fracture hackly.

Comp.-Pure copper, but often containing some silver, bismuth, etc.
Pyr., etc.-B.B., fuses readily ; on cooling, becomes covered with a coating of black oxiae. Dissolves readily in nitric acid, giving off red nitrous fumes, and producing a deep azure-blue solution upon the addition of ammonia.

Obs.-Copper occurs in beds and veins accompanying its various ores, and is most abundant in the vicinity of dikes of igneous rocks. It is sometimes found in loose masses imbedded in the soil.

Found at Turinsk, in the Urals, in fine crystals. Common in Cornwall. In Brazil, Chili, Bolivia, and Peru. At Walleroo, Australia.

This metal has been found native throughout the red sandstone (Triassico-Jurassic) region of the eastern United States, in Massachusetts, Connecticut, and more abundantly in New Jersey, where it has been met with sometimes in fine crystalline masses. No known locality exceeds in the abundance of native copper the Lake Superior copper region, near Keweenaw Point, where it exists in veins that intersect the trap and sandstone, and where masses of immense size have been obtained. It is associated with prehnite, dutolite, analcite, laumontite, pectolite, epidote, chlorite, wollastonite, and sometimes coats amygdules of calcite, etc., in amygdaloid. Native copper occurs sparingly in California. Also on the Gila river in Arizona: in large drift masses in Alaska.

## IRON.*

Isometric. Cleavage octahedral.
H. $=4 \cdot 5$. G. $=7 \cdot 3-7 \cdot 8$. Lustre metallic. Color iron-gray. Streak shin ing. Fracture hackly. Malleable. Acts strongly on the magnet.

Obs,-The occurrence of masses of native iron of terrestrial origin has been several times reported, but it is not yet placed beyond doubt. The presence of metallic iron in grains in basaltic rocks has been proved by several observers. It has also been noticed in other related rocks. The so-called meteoric iron of Ovifak, Greenland, found imbedded in basalt, is considered by some autbors to be terrestrial.

Meteoric iron usually contains 1 to 20 per cent. of nickel, besides a small percentage of other metals, as cobalt, manganese, tin, copper, chromium ; also phosphorus common as a phosphuret (schreibersite), sulphur in sulphurets, carbon in some instances, chlorine. Among large iron meteorites. the Gibbs meteorite, in the Yale College cabinet, weighs 1,635 lbs.; it was brought from Red River. The Tucson meteorite, now in the Smithsonian Institution, weighs 1,400 lbs. ; it was originally from Sonora. It is ring-shaped, and is 49 inches in its greatest diameter. Still more remarkable masses exist in northern Mexico; also in South America; one was discovered by Don Rubin de Celis in the district of Chaco-Gualamba, whose weight was estimated at $32,000 \mathrm{lbs}$. The Siberian meteorite, discovered by Pallas, weighed originally $1,600 \mathrm{lbs}$. and contained imbedded crystals of chrysolite. Smaller masses are quite common.

ZINC.--Native zinc has been reported to occur in Australia; and more recently Mr. W. D. Marks reports its discovery in Tennessee, under circumstances not altogether free from doubt.

LEAD.-Native lead occurs very sparingly. It has been found in the Urals, in Spain, Ireland, etc. Dr. Genth speaks of its discovery in the bed rock of the gold placers at Camp Creek, Montana.

Tin is probably only an artificial product.

## arsenic. $\varnothing$

Rhombohedral. $R \wedge R=85^{\circ} 41^{\prime}, O \wedge R=122^{\circ} 9^{\prime}, \dot{c}=1 \cdot 3779$, Miller. Cleavage: basal, imperfect. Often granular massive; sometimes reticulated, reniform, and stalactitic. Structure rarely columnar.
H. $=3 \cdot 5$. G. $=5 \cdot 93$. Lustre nearly metallic. Color and streak tin-white, tainishing soon to dark-gray. Fracture uneven and fine granular.

Comp.-Arsenic, often with some antimony, and traces of iron, silver, gold, or bismath.
Pyr.-B.B., on charcoal volatilizes without fusing, coats the coal with white arsenous oxide, and affords the odor of garlic; the coating treated in R.F. volatilizes, tinging the flame blue.
Obs.-Native arsenic commonly occurs in veins in crystalline rocks and the older schists, and is often accompanied by ores of antimony, red silver ore, realgar, sphalerite, and other metallic minerals.
The silver mines of Saxony afford this metal in considerable quantities; also Bohemia, the Harz, Transylvania, Hungary, Norway, Siberia; occurs at Chanarcillo, and elsewhere in Chili; and at the mines of San Augustin, Mexico. In the United States it has been observed at Haverhill and Jackson, N. H., at Greenwood, Me.

## ANTIMONY.

Rhombohedral. $R \wedge R=87^{\circ} 35^{\prime}$, Rose ; $O \wedge R=123^{\circ} 32^{\prime} ; \dot{c}=1 \cdot 3068$. $2 \wedge 2=89^{\circ} 25^{\prime}$. Cleavage : basal, highly perfect; $-\frac{1}{2}$ distinct. Generally massive, lamellar ; sometimes botryoidal or reniform with a granular texture

[^29]$\mathrm{H} .=3-3 \cdot 5$. G. $=6 \cdot 046-6 \cdot 72$. Lustre metallic. Color and streak tinwhite. Very brittle.

Comp,-Antimony, containing sometimes silver, iron, or arsenic.
Pyr,-B.B., on charcoal fuses, gives a white coating in both O. and R.F.; if the blowing be intermitted, the globule continues to glow, giving off white fumes, until it is finally crusted over with prismatic crystals of antimonous oxide. The white coating tinges the R.F. bluishgreen. Crystallizes readily from fusion.

Occurs near Sahl in Sweden; at Andreasberg in the Harz; at Przibram; at Allemont in Dauphiny; in Mexico; Chili ; Borneo ; at South Ham, Canada ; at Warren, N. J., rare ; at Prince Willian antimony mine, N. Brunswick, rare.

Allemontite.-Arsenical antimony, $\mathrm{SbAs}_{3}$. Color tin-white or reddish-gray. Occurs at Allemont ; in Bohemia ; the Harz.

BISMUTH. Gediegen Wismuth, Germ.
Hexagonal. $R \wedge R=87^{\circ} 40^{\prime}$, G. Rose ; $O \wedge R=123^{\circ} 36^{\prime} ; \dot{c}=1 \cdot 3035$. Cleavage : basal, perfect; 2, -2 , less so. Also in reticulated and arbcrescent shapes; foliated and granular.
II. $=2-2 \cdot 5 . \quad$ G. $=9 \cdot 727$. ${ }^{2}$ Lustre metallic. Streak and color silver-white, with a reddish hue; subject to tarnish. Opaque. Fracture not observable. Sectile. Brittle when cold, but when heated somewhat malleable.

Comp., Var.-Pure bismuth, with occasional traces of arsenic, sulphur, tellurium.
Pyr., etc.-B.B., on charcoal fuses and entirely volatilizes, giving a coating orange-yellow while hot, and lemon-yellow on cooling. Dissolves in nitric acid ; subsequent dilution cnusea n white precipitate. Crystallizes readily from fusion.
Diff-Distinguished by its reddish color, and high specific gravity, from the other brittle metals.
Obs.-Bismuth occurs in veins in gneiss and other crystalline rocks and clay slate, accompanying various ores of silver, cobalt, lead, and zinc. Abundant at the silver and cobalt mines of Saxony and Bohemia; also found in Norway, and at Fahlun in Sweden. At Wheal Sparnon, and elsewhere in Cornwall, and at Carrack Fell in Cumberland ; at the Atlas mine, Devonshire ; at Meymac, Corrèze ; at San Antonio, Chili ; Mt. Illampa (Sorata), in Bolivia; in Victoria.
At Lane's mine in Monroe, and near Seymorr, Conn., in quartz ; occurs also at Brewer'я mine, Chesterfield district, South Carolina; in Colorado.

## TELLURIUM.*

Hexagonal, $R \wedge R=86^{\circ} 57^{\prime}$, G. Rose ; $O \wedge R=123^{\circ} 4^{\prime}, \dot{c}=1 \cdot 3302$. In six-sided prisms, with basal edges replaced. Cleavage: lateral perfect, basal imperfect. Commonly massive and granular.
$\mathrm{H} .=2-2 \cdot 5 . \quad \mathrm{G} .=6 \cdot 1-6 \cdot 3 . \quad$ Lustre metallic. Color and streak tin-white. Brittle.

[^30]
## NATIVE SULPHUR.

Orthorhombic. $I \wedge I=101^{\circ} 46^{\prime}, O \wedge 1-\bar{\imath}=113^{\circ} 6^{\prime} ; \dot{c}: \bar{b}: \check{a}=2 \cdot 344^{\circ}$ $1 \cdot 23$ : 1. $O \wedge 1-\check{\imath}=117^{\circ} 41^{\prime} ; O \wedge 1=108^{\circ} 19^{\prime}$.

Cleavage: $I$, and 1, imperfect. Twins, 416417 . composition-face, $I$, sometimes producing cruci-
 form crystals. Also massive, sometimes con sisting of concentric coats.
$\mathrm{H} .=1 \cdot 5-2 \cdot 5$. G. $=2 \cdot 072$, of crystals from Spain. Lirstre resinous. Streak sulphur-yellow, sometimes reddish or greenish. Trans-parent-subtranslucent. Fracture conchoidal, inore or less perfect. Sectile.

Comp.-Pure sulphur ; but often contaminated with clay or bitumen.
Pyr., etc.- Burns at a low temperature with a bluish flame, with the strong odor of sulphurous oxide. Becomes resinously electrified by friction. Insoluble in water, and not acted on by the acids.

Obs.-Sulphur is dimorphous, the crystals being monoclinic when formed at a moderately high temperature ( $125^{\circ} \mathrm{C}$., according to Frankenheim).

The great repositories of sulphur are either beds of gypsum and the associate rocks, or the regions of active and extinct volcanoes. In the valley of Noto and Mazarro, in sicily; at Conil, near Cadiz, in Spain; Bex, in Switzerland; Cracow, in Poland, it occurs in the former situation ; also Bologna, Italy. Sicily and the neighboring volcanic isles; the Solfatara, near Naples; the volcanoes of the Pacific ocean, etc., are localities of the latter kind. Abundant in the Chilian Andes.

Sulphur is found near the sulphur springs of New York, Virginia, etc., sparingly; in many coal deposits and elsewhere, where pyrite is undergoing decomposition; at the hot springs and geysers of the Yellowstone park ; in California, at the geysers of Napa valley, Sonoma Co. ; in Santa Barbara in good crystals; near Clear lake, Lake Co. ; in Nevada, in Humboldt Co., iu large beds; Nye and Esmeralda Cos., etc.

The sulphur mines of Sicily, the crater of Vulcano, the Solfatara near Naples, and the keds of California, afford large quantities of sulphur for commerce.

## DIAMOND.*

Isometric. Often tetrahedral in planes, 1, 2, and $3-\frac{3}{2}$. Usually witl

curved faces, as in f. $419\left(3-\frac{3}{2}\right)$; f. 420 is a distorted form. Clearage : octahedral, highly perfect. Twins: twinning-plane, octahedral; f. 418, is
an elliptic twin of f .419 , the middle portion between two opposite sets of six planes being wanting. Rarely massive.
H. $=10$. G. $=3.5295$, Thompson. Lustre brilliant adamantine. Color white or colorless: occasionally tinged yellow, red, orange, green, blue, brown, sometimes black. Transparent; translucent when dark colored. Fracture conchoidal. Index of refraction 244 . Exhibits vitreous electricity when rubled.

Comp.-Pure carbon, isometric in crystallization.
Var.-1. Ordinary, or crystallized. The crystals often contain numerous microscopic cavnties, as detected by Brewster; and around these cavities the diamond shows evidence, by polarized light, of compression, as if from pressure in the included gas when the diamond was crystallized. The coarse varieties, which are unfit, in consequence of imperfections, for use in jewelry, are called bort; they are sold to the trade for cutting purposes.
2. Massive. In black pebbles or masses, called carbonado, occasionally 1,000 carats in weight. $\mathrm{H}=10 ; \mathrm{G} .=3.012-3.416$. Consists of pure carbon, excepting 0.27 to 2.07 p . c. (Brazil).
3. Antlurucitic. Like anthracite, but hard enough to scratch even the diamond. In globules or mammillary masses, consisting partly of concentric layers; fragile; G. $=1 \cdot 66$; composition, Carbon 97 , hydrogen $0 \cdot 5$, oxygen $1 \cdot 5$. Cut in facets and polished, it refracts and disperses light, with the white lustre peculiar to the diamond. Locality unknown, but supposed to come from Brazil.

Pyi., ets.-Burns, and is wholly consumed at a high temperature, producing carbonic dioxide. It is not acted on by acids or alkalies.

Diff.-Distingu shed by its extreme hardness, brilliancy of reflection, and adamantine lustre.
Obs - The diamond often occurs in regions that afford a laminated granular quartz rocii, called itucolumyte, which pertains to the talcose series, and which in thin slabs is nore or less flexible. This rock is found at the mines of Brazil and the Urals; and also in Georgia and North Carolina, where a few diamonds hove been found. It has also been detected in a species of conglomerate, composed of rounded siliceous pebbles, quartz, chalcedony, etc., cemented, by a kind of ferruginous clay. Diamonds are usually, however, washed out from the soil. The Ural diamonds occur in the detritus along the Adolfskoi rivulet, where worked for crold, and also at other places. In India the diamond is met with at Purteal, between Hyderabad and Masulipatam, where the famous Kohinoor was found. The locality on Borneo is at Pontiana, on the west side of the Ratoos mountain. Also found in Australia.

The diamond region of South Africa, discovered in 1816 , is the most productive at the present time. The diamonds occur in the gravel of the Vaal river, from Potchefstrôm, capital of the Transvaal Republic, down its whole course to its junction with the Orange river, and thence along ths latter stream for a distance of 60 miles. In addition to this the diamonds are found also in the Orange River Republic, in isolated fields or Pans, of which Du Toit's Pan is the most famous. The number of diamonds which have been found at the Cape is very large, and some of them are of considerable size. It has been estimated that the value of those obtained from March, 1867, to November, 1875, exceeded sixty millions of dullars. As a consequence of this production the market value of the stones has been much diminished.
In the United States a few crystals have been met with in Rutherford Co., N. C., and Hall Co., (ia.; they occur also at Portis mine, Franklin Co., N. C. (Genth); one handsome one, over $\frac{1}{8}$ in. in diameter, in the village of Manchester, opposite Richmond, Va. In California, at Cherokee ravine, in Butte Co.; also in N. San Juan, Nevada Co., and elsewhere in the gold washings. Reported from Idaho, and with platinum of Oregon.

The largest diamond of which we have any knowledge is mentioned by Tavernier as in possession of the Great Mogul. It weighed originally 900 carats, or 27693 grains, but was reduced by cutting to 861 grains. It has the form and size of half a hen's egg. It was found in 1550 , in the mine of Colone. The Pitt or Regent diamond weighs but $136 \cdot 25$ carats, or $419 \frac{1}{4}$ grains; but is of unblemished transparency and color. It is cut in the form of a brilliant, and its value is estimated at £125.000. The Kohinoor measured, on its arrival in Erigland, about $1 \frac{5}{8}$ inches in its greatest diameter, over $\frac{5}{8}$ of an inch in thickness, and weighed 186 carats, and was cut with many facets. It has since been recut, and reduced to a diamuter of $1-\frac{7}{2}$ by $1 \frac{8}{8}$ nearly, and thus diminished over one-third in weight. It is supposed by ML. 'Tennant to have been originally a dodecahedron, and he suggests that the great Russian diamond and another large slab weighing 130 carats were actuslly cut from the original lodecahedron. Tavernier gives the original weight at $787 \frac{1}{2}$ carats. The Rajah of Mattan has in his possestion a diamond from Borneo, weighing 367 carats. The mines of Brazil were not known to afford diamonds till the cemmencement of the eighteenth century.

## X Graphite. Plumbago.

Hexagonal. In flat six-sided tables. The basal planes $(O)$ are ofteu striated parallel to the alternate edges. Cleavage: basal, perfect. Commonly in imbedded, foliated, or granular masses. Rarely in globular concretions, radiated in structure.
$\mathrm{H} .=1-2 . \quad \mathrm{G} .=2 \cdot 09-2 \cdot 229$. Lustre metallic. Streak black and shining. Color iron-black-dark steel-gray. Opaque. Sectile; soils paper. Thin laminæ flexible. Feel greasy.

Var.-(a) Foliated; (b) columnar, and sometimes radiated; (c) scaly, massive, and slaty ; (d) granular massive; (e) earthy, amorphous, without metallic lustre except in the streak; ( $f$ ) in radiated concretions.

Comp.-Pure carbon, with often a little iron sesquioxide mechanioally mixed.
Pyr., etc.-At a high temperature it burns without flame or smoke, leaving usually some red oxide of iron. B.B. infusible; fused with nitre in a platinum spoon, deflagrates, converting the reagent into potassium carbonate, which effervesces with acids. Unaltered by acids.

Diff.-See molybdenite, p. 233.
Obs.-Graphite occurs in beds and imbedded masses, laminæ, or scales, in granite, gneiss, mica schists, crystalline limestone. It is in some places a result of the alteration by heat of the coal of the coal formation. Sometimes met with in greenstone. It is a common furnace product.

Occurs at Borrowdale in Cumverland ; in Glenstrathfarrar in Invernesshire ; at Arendal in Norway; in the Urals, Siberia, Finland; in various parts of Austria; Prussia; France. Large quantities are brought from the East Indies.

In the United States, the mines of Sturbridge, Mass., of Ticonderoga and Fishkill, N. Y., of Brandon, Vt., and of Wake, N. C., are worked; and that of Ashford, Conn., formerly afforded a large amount of graphite. It occurs sparingly at many other localities.

The name black lead, applied to this species, is inappropriate, as it contains no lead. The name graphite, of Werner, is derived from $\gamma \rho a ́ \phi w, ~ t o ~ w r i t e . ~ . ~$

Nordenskiöld makes the graphite of Ersby and Storgard monoclinic.

## IJ. SULPHIDES, TELLURIDES, SELENIDES, ARSENIDES, BISMUTHIDES.

## 1. BINaRY COMPOUNDS.-Sulphides and Tellurides of the Metals of the Sulphur and Arsenic groups.



Monoclinic. $\quad C^{\prime}=66^{\circ} 5^{\prime}, I \wedge I=74^{\circ} 26^{\prime}$, Marignac, Scacchi, $O \wedge 1-i=$ $138^{\circ} 21^{\prime}$; $\dot{c}: b: a ̀=0.6755: 0.6943: 1$. Habit prismatic. Cleavage: $i-i, O$ rather perfect; $I, i-i$ in
 traces. Also granular, coarse or fine ; compact.
$H .=1 \cdot 5-2$. G.$=3 \cdot 4-3 \cdot 6$. Lustre resinous. Color aurora-red or orange-yellow. Streak varying from orange-red to aurora-red. Transparent-translucent. Fracture conchoidal, uneven.

Comp,-AsS=Sulphur 29.9, arsenic $70 \cdot 1=100$.
Pyr., etc.-In the closed tube melts, volatilizes, and gives a transparent red sublimate; in the open tube, sulphurous fumes, and a white crystalline sublimate of arsenous oxide. B.B. on hlarcoal burns with a blue flame, emitting arsenical and sulphurous odors. Soluble in caustic alkalies.

Obs.-Occurs with ores of silver and lead, in Upper Hungary ; in Transylvania ; at Joachimsthal; Schneeberg; Andreasberg; in the Binnenthal, Switzerland, in dolomite ; at Wiesloch in Baden; near Julamerk in Koordistan ; in Vesuvian lavas, in minute crystals.

## ORPIMENT.*

Orthorhombic. $I \wedge I=100^{\circ} 40^{\prime}, O \wedge 1-\bar{\imath}=126^{\circ} 30^{\prime}$, Mohs. $\quad c: \bar{b}: \breve{a}=$ $1 \cdot 3511$ : 1-2059:1. Cleavage : $i-\imath$ highly perfect, $i-\check{\iota}$ in traces. $i-\check{\iota}$ longitudinally striated. Also, massive, foliated, or columnar ; sometimes reniform.
$\mathrm{H} .=1 \cdot 5-2 . \quad \mathrm{G} .=3 \cdot 48$, Haidinger. Lustre pearly upon the faces of perfect cleavage ; elsewhere resinous. Color several shades of lemon-yellow. Streak yellow, commonly a little paler than the color. Subtransparentsubtranslucent. Sub-se itile. Thin laminæ obtained by cleavage flexible but not elastic.

[^31]the Solfatara near Naples. Near Julamerk in Koordistan. Occurs also at Acobambillo, Pera. Small traces are met with in Edenville, Orange Co., N. Y.

The name orpiment is a corruption of its Latin name auripigmentum, "golden paint," which was given in allusion to the color, and also because the substance was supposed to contain gold.

Dimorphite of Scacchi may be, according to Kenngott, a variety of orpiment.

STIBNITE. Antimonite. Gray Antimony. Antimony Glance. Antimonglanz, Gernc.
Orthorhombic. $I \wedge I=90^{\circ} 54^{\prime}, O \wedge 1-\bar{\imath}=134^{\circ} 16^{\prime}$, Krenner; $\dot{c}: \bar{b}: \breve{a}=$ $1 \cdot 0259: 1.0158: 1 . \quad O \wedge 1=124^{\circ}$
 $45^{\prime} ; O \wedge 1-\check{\imath}=134^{\circ} 42 \frac{1^{\prime}}{2}$.

Lateral planes deeply striated longitudinally. Cleavage $: i-乞$ highly perfect. Often columnar, coarse or tine ; also granular to impalpable.
$H .=2 . G .=4 \cdot \breve{3} 16$, Haüy. Lustre metallic. Color and streak leadgray, inclining to steel-gray: subject to blackish tarnish, sometimes iridescent. Fracture small sub-conchoidal. Sectile. Thin lamina a little tlexible.

Comp.- $\mathrm{Sb}_{2} \mathrm{~S}_{3}=$ Sulphur 28:2, antimony $71 \cdot 8=100$.
Pyr., etc, -In the open tube sulphurous and antimonous fumes, the latter condensirg as a white sublimate which B.B. is non-volatile. On charcoal fuses, spreads out, gives sulphurous and antimonous fumes, coats the coal white; this coating treated in R.F. tinges the flame greenish-blue. Fus. $=1$. When pure perfectly soluble in hydrochloric acid.

Diff - Distinguished by its perfect cleavage; also by its extreme fusibility and other blowpipe characters.

Ob-Occurs with spathic iron in beds, but generally in veins. Often associated with blende, barite, and quartz.

Met with in veins at Wolfsberg, in the Harz ; at Brïunsdorf, near Freiberg ; at Przibram ; in Hungary; at Pereta, in Tuscany; in the Urals ; in Dumfriesshire ; in Cornwall. Also found in different Mexican mines. Also abundant in Borneo.

In the United States, it occurs sparingly at Carmel, Me. ; at Cornish and Lyme, N. H. ; at "Soldier's Delight," Md.; in the Humboldt mining region in Nevada; also in the mines of Aurora, Esmeralda Co., Nevada. Also found in New Brunswick, 20 m . from Fredericton, S. W. side of St. John R.

This ore affords much of the antimony of commerce. The crude antimony of the shops is obtained by simple fusion, which separates the accompanying rock. From this product most of the pharmaceutical preparations of antimony are made, and the pure metal extracted.

Livingstonite (Barcena).-Resembles stibnite in physical characters, but has a red streak, and contains, besides sulphur and antimony, 14 p. c. mercury. Huitzuco, State of Guerrero, Mexico. See p. 430.

BISMUTHINITE. Bismuth Glance. Wismuthglanz, Germ.

Orth orhombic. $I \wedge I=91^{\circ} 30^{\prime}$, Haidinger. perfect ; macrodiagonal less so ; basal perfect.

Clearage: brachydiagonal In acicular crystals. Also uassive, with a foliated or fibrous structure.
II. $=2$. G. $=6 \cdot 4-6 \cdot 459 ; 7 \cdot 2 ; 7 \cdot 16$, Bolivia, Forbes. Lustre metallic. Streak and color lead-gray, inclining to tin-white, with a yellowish or irides. ceut tarnish. Opaque.

Comp. $-\mathrm{Bi}_{2} \mathrm{~S}_{3}=$ Sulphur 18.75 , bismuth $81 \cdot 25=100$; isomorphous with stibnite.
Pyr., etc.-In the open tube sulphurous fumes, and a white sublimate which B.B. fuses into drops, brown while hot and opaque yellow on cooling. On charcoal at first gives sulphurous fumes, then fuses with spirting, and coats the coal with yellow bismuth oxide. F'us =1. Dissolves readily in hot nitric acid, and a white precipitate falls on diluting with water.

Obs.-Found at Brandy Gill, Carrock Fells, in Camberland ; near Redruth; at Botallack near Land's End; at Herland Mine, Gwennap; with childrenite, near Callington; in Saxony; at Riddarhyttan, Sweden; near Sorata, Bolivia. Occurs in Rowan Co., N. C., at the Barnhardt vein ; at Haddam, Ct. ; Beaver Co., Utah.

Gunnajuatite ; F'renzelite. Fernandez, 1873 ; Castillo, 1873 ; Frenzel, 1874.-A bismuth selenide, $\mathrm{Bi}_{2} \mathrm{Se}_{3}$; sometimes with part of the selenium replaced by sulphur, that is, $\mathrm{Bi}_{2}(\mathrm{Se}, \mathrm{S})_{3}$, with $\mathrm{Se}: \mathrm{S}=3: 2$, which requires Selenium $23 \cdot 8$, sulphur $6 \cdot 5$, bismuth $697=100$. Isomorphous with stibnite and bismuthinite (Schrauf). Guanajuato, Mexico. Silaonite from Guanajuato is $\mathrm{Bi}_{3} \mathrm{Se}$ (Fernandez). See p. 428.

- TETRADYMITE. Tellurwismuth, Germ.

Hexagonal. (O^R=118 $38^{\prime}, R \wedge R=81^{\circ} 2^{\prime} ; \dot{c}=1 \cdot 5865$. Urystals often tabular. Cleavage : basal, very perfect. Also massive, foliated, or granular.
$\mathrm{H} .=1 \cdot 5-2 . \quad \mathrm{G} .=7 \cdot 2-7 \cdot 9$. Lustre metallic, splendent. Color pale steelgray. Not very sectile. Laminæ flexible. Soils paper.

Comp., Var.-Consists of bismuth and tellurium, with sometimes sulphur and selenium. It sulphur, when present, replaces part of the tellurium, the analyses for the most part afford the general formula $\mathrm{Bi}_{2}(\mathrm{Te}, \mathrm{S})_{3}$. Var. 1. - Free from sulphur. $\mathrm{Bi}_{2} \mathrm{Te}_{3}=$ Tellurium $48 \cdot 1$, bismuth 51.9 ; G. $=7 \cdot 868$, from Dahlonega, Jackson; $7 \cdot 642$, id., Balch. 2. Sulphurous. Containing 4 or 5 p. c. sulphur. $G_{0}=7 \cdot 500$, crystals from Schubkau, Wehrle.
Pyr.-In the open tube a whit, sublimate of tellurous oxide, which B.B. fuses to colorless drops. On charcoal fuses, gives white fumes, and entirely volatilizes; tinges the R.F. bluishgreen; coats the coal at first white (tellurous oxide), and finally orange-yellow (bismuth oxide); some varieties give sulphurous and selenous odors.

Diff.-Distinguished by its easy fusibility ; tendency to foliation, and high specific gravity.
Obs.-Occurs at Schubkau, near Schemnitz; at Retzbanya; Orawicza; at Tellemark in Norway; at Bastnaes mine, near Riddarhyttan, Sweden.

In the United States, associated with gold ores, in Virginia ; in North Carolina, Davidson Co., etc. Also occurs in Georgia, 4 m . E. of Dahlonega, and elsewhere; Highland, Montana T. ; Red Cloud mine, Colorado, rare ; Montgomery mine, Arizona.

Joseite.-A bismuth telluride, in which half the tellurium is replaced by sulphur and selenium ; Brazil.

Wehrlite.-Composition probably $\operatorname{Bi}(\mathrm{Te}, \mathrm{S})$. G. $=8 \cdot 44$. Deutsch Pilsen, Hungary.

## MOLYBDENITE.* Molybdänglanz, Germ.

In short or tabular hexagonal prisms. Cleavage: eminent, parallel to base of hexagonal prisms. Commonly foliated, massive, or in scales: alse tine granular.
$\mathrm{H} .=1-1.5$, being easily impressed by the nail. G. $=4 \cdot 44-4.8$. Lustre metallic. Color pure lead-gray. Streak similar to color, slightly inclined to green. Opaque. Laminæ very flexible, not elastic. Sectile, and almost malleable. Bluish-gray trace on paper.

Comp. $-\mathrm{MoS}_{2}=$ Sulphur $41^{\circ} 0$, molybdenum $5 \bar{y} \cdot 0=100$.
Pyr., etc.-In the open tube sulphurous fumes. B.B. in the forceps infusible, imparts a yellowish-green color to the flame; on charcoal the pulverized mineral gives in O.F. a strong odor of sulphur, and coats the coal with crystals of molybdic oxide, which appear yellow while hot, and white on cooling; near the assay the coating is copper-red, and if the white coating be touched with an intermittent R.F., it assumes a beautiful azure-blue color. Decomposed by nitric acid, leaving a white or grayish residue (molybdic oxide).

Diff.-Distinguished from graphite by its color and streak, and also by its behavior (yielding sulphur, etc.) before the blowpipe.

Obs-Molybdenite generally occurs imbedded in, or disseminated through, granite, gneiss, zircon-syenite, granular limestone, and other crystalline rocks. Found in Sweden; Norway; Russia. Also in Saxony ; in Bohemia; Rathausberg in Austria ; near Miask, Urals; Chessy in France; Peru eBrazil; Calbeck Fells, and elsewhere in Cumberland ; several of the Cornish mines; in Scotland at East Tulloch, etc.

In Maine, at Blue Hill Bay and Camdage farm. In Conn., at Haddam. In Vermont, at Newport. In N. Hampshire, at Westmoreland; at Llandaff; at Franconia. In Mass., at Shutesbury; at Brimfield. In N. York, near Warwick. In Penn., in Chester, on Chester Creek; near Concord, Cabarrus Co., N. C. In California, at Excelsior gold mine, in Excelsior district. In Canada, at several places.

## 2. Binary Compounds.-Sulphides, Tellurides, etc., of Metals of the Gold, Iron, and Tin Groups.

## A. BASIC DIVISION.

DYSCRASITE. Antimonial Silver. Antimon-Silber, Germ.
Orthorhombic. $I \wedge I=119^{\circ} 59^{\prime} ; O \wedge 1-\bar{\imath} 130^{\circ} 41^{\prime} ; \dot{c}: \bar{b}: \check{a}=1 \cdot 1633$ : $1 \cdot 7315: 1 ; 0 \wedge 1=126^{\circ} 40^{\prime} ; O \wedge 1-\check{\imath}=146^{\circ} 6^{\prime}$. Cleavage : basal distinct : $1-\zeta$ also distiuct; $I$ imperfect. Twins: stellate forms and hexagonal prisms. Prismatic planes striated vertically. Also massive, granular; particles of various sizes, weakly coherent.
H. $=3 \cdot 5-4$. G. $=9 \cdot 44-9 \cdot 82$. Lustre metallic. Color and streak silverwhite, inclining to tin-white; sometimes tarnished yellow or blackish. Opaque. Fracture uneven.

Comp.- $\mathrm{Ag}_{4} \mathrm{Sb}=$ Antimony 22, silver $78=100$. Also $\mathrm{Ag}_{6} \mathrm{Sb}=$ Antimony $15 \cdot 66$, silver $84 \cdot 34$, and other proportions.

Pyr., etc.-B.B. on charcoal fuses to a globule, coating the coal with white antimonous oxide, and finally giving a globule of almost pure silver. Soluble in nitric acid, leaving antimonous oxide.

Obs.-Occurs near Wolfach in Baden, Wittichen in Suabia, and at Andreasberg; also at Allemont in Dauphiné, Casalla in Spain, and in Bolivia, S. A.

## DOMEYKITE. Arsenikkupfer, Germ.

Reniform and botryoidal ; also massive and disseminated.
H. $=3-3 \cdot 5$. G. $=7-7 \cdot 50$, Portage Lake, Genth. Lustre metallic but dull on exposure. Color tin-white to steel-gray, with a yellowish to pinchbeckbrown, and, afterward, an iridescent tarnish. Fracture uneven.

Comp.-Cu $\mathrm{Cu}_{3} \mathrm{As}=$ Arsenic 28.3 , copper ${ }^{7} 1 \cdot 7=100$.
Pyr., etc.-In the open tube fuses and gives a white crystalline sublimate of arsenous oxide. B.B. on charcoal arsenical fumes and a malleable metallic globule, which, on treat. ment with soda, gives a globule of pure copper. Not dissolved in hydrochloric acid, but soluble in nitric acid.

Obs.-From the mines of Chili. In N. America, found on the Sheldon location, Portage Lake; and at Michipicoten Island, in L. Superior.

Algononite. - Composition, $\mathrm{Cu}_{6} \mathrm{As}=$ Arsenic $16 \cdot 5$, copper 83.5 . Chili ; also Lake Superior.
Whitnelite.- $\mathrm{Cu}_{9}$ As=Arsenic $11 \cdot 6$, copper $88 \cdot 4=100$. Houghton, Mich., also California, Arizona.

## B. PROTO DIVISION.

## (a) Galenite Group. Isometric; holohedral.

ARGENTITE. Silver Glance. Vitreous Silver. Silberglanz, Germ.
Isometric. Cleavage : dodecahedral in traces. Also reticulated, arborescent, and filiform ; also amorphous.
H. $=2-2 \cdot 5$ G. $=7 \cdot 196-7 \cdot 365$. Lustre metallic. Streak and color black. ish lead-gray ; streak shining. Opaque. Fracture small sub-conchoidal, meven. Malleable.

Comp. $-\mathrm{Ag}_{2} \mathrm{~S}=$ Sulphur $12 \cdot 9$, silver $87 \cdot 1=100$.
Pyr., etc.-In the open tabe gives off sulphurous oxide. B.B. on charcoal fuses with intumescence in O.F., emitting sulphurous fumes, and yielding a globule of silver.

Diff.-Distinguished from other silver ores by its malleability.
Obs.-Found in the Erzgebirge ; in Hungary ; in Norway, near Kongsberg ; in the Altai; in the Urals at the Blagodat mine; in Cornwall; in Bolivia; Peru; Chili; Mexico, etc. Occurs in Nevada, at the Comstock lode, and elsewhere.
Oldiamite from the Busti meteorite is essentially CaS.
Nadmannite.-A silver selenide, containing also some lead. Color iron-black. From the Harz.
EuCairite.-A silver-copper selenide, $(\mathrm{Cu}, \mathrm{Ag})_{2} \mathrm{Se}$. Color silver-white to gray. Sweden; Chili.

## CROOKESITE.

Massive, compact; no trace of crystallization.
$\mathrm{H} .=2 \cdot 5-3$. G. $=6 \cdot 90$. Lustre metallic. Color lead-gray. Brittle.
Comp.- $\left(\mathrm{Cu}_{2}, \mathrm{Tl}, \mathrm{Ag}\right) \mathrm{Se}=$ Selenium $33 \cdot 28$, copper 45 $\cdot 76$, thallium $17 \cdot 25$, silver $3 \cdot 71=10$.
Pyr., ets.-B.B. fuses very easily to a greenish-black shining enamel, coloring the flame strongly green. Insoluble in hydrochloric acid ; completely soluble in nitric acid.

Obs.-From the mine of Skrikerum in Norway. Formerly regarded as selenide of copper or berzelianite.

## GALINITEE. Galena. Bleiglanz, Germ.

Isometric ; hahit cubic (see f. 38, 39, etc., p. 15). Cleavage, cubic, perfeet; octahedral in traces. Twins: twinning-plane, the octahedral plane, f. 42.5 (f. 263, p. 88); the same kind of composition repeated, f. 426 , and
flattened̈ parallel to 1. Also reticulated, tabular ; coarse or fine grantlar ; sometimes impalpable ; occasionally fibrous.

$\mathrm{H} .=2 \cdot 5-2 \cdot 75 . \quad \mathrm{G} .=7 \cdot 25-7 \cdot 7$. Lustre metallic. Color and streak pure lead-gray. Surface of crystals occasionally tarnished. Fracture flat subchonchoidal, or even. Frangible.

Comp., Var.-PbS=Sulphur $13 \cdot 4$, lead $86 \cdot 6=100$. Contains silver, and occasionally selenium, zinc, cadmium, antimony, copper, as sulphides; besides, also, sometimes native silver and gold; all galenite is more or less argentiferous, and no external characters serve to distinguish the relative amount of silver present.

Pyr.-In the open tube gives sulphurous fumes. B.B. on charcoal fuses, emits sulphurous fumes, coats the coal yellow, and yields a globule of metallic lead. Soluble in nitric acid.

Diff.-Distinguished in all but the finely granular varieties by its perfect cubic cleavage.
Obs.-Occurs in beds and veins, both in crystalline and uncrystalline rocks. It is often associated with pyrite, marcasite, blende, chalcopyrite, arsenopyrite, etc., in a gangue of quartz, calcite, barite, or fluorite, etc. ; also with cerussite, anglesite, and other salts of lead, which are frequent results of its alteration. It is also common with gold, and in veins of silver ores. Some prominent localities are:-Freiberg in Saxony, the Harz, Przibram and Joachimsthal, Styria; and also Bleiberg, and the neighboring localities of Carinthia, Sala in Sweden, Leadhills and the killas of Cornwall, in veins; Derbyshire, Cumberland; and the northern districts of England; in Nertschinsk, East Siberia; in Algeria; near Cape of Good Hope; in Australia; Chili; Bolivia, etc.

Extensive deposits of this ore in the United States exist in Missouri, Illinois, Iowa, and Wisconsin. Other important localities are:-in Nero York, Rossie, St. Lawrence Co. : Wurtzboro, Sullivan Co.; at Ancram, Columbia Co.; in Ulster Co. In Maine, at Lubec. In New Hampshire, at Eaton and other places. In Vermont, at Thetford. In Connecticut, at Middletown. In Massachusetts, at Newburyport, at Southampton, etc. In Pennsylvonia, at Phenixville and elsewhere. In Virginia, at Austin's mines in Wythe Co., Walton's gold mine in Louisa Co., etc. In Tennessee, at Brown's Creek, and at Haysboro, near Nashville. In Michigan, in the region of Chocolate river, and Lake Superior copper districts, on the N. shore of L. Superior, in Neebing on Thunder Bay, and around Black Bay. In California, at many of the gold mines. In Nevada, abundant on Walker's river, and at Steamboat Springs, Galena district. In Arizona, in the Castle Dome, Eureka, and other districts. In Colorado, at Pike's Peak, etc.

## CLAUSTHALITE. Selenblei, Germ.

Isometric. Occurs commonly in fine granular masses; some specimens foliated. Cleavage cubic.
$\mathrm{H} .=2 \cdot 5-3 . \quad \mathrm{G} .=7 \cdot 6-8 \cdot 8 . \quad$ Lustre metallic. Color lead-gray, somewhat bluịsh. Streak darker. Opaque. Fracture granular and shining.

Comp., Var.- $\mathrm{PbSe}=$ Selenium $27 \cdot 6$, lead $i 2 \cdot 4=100$. Besides the pure selenide of lead, there are others, often arranged as distinct species, which contain cobalt, copper, or mercury in place of part of the lead, and sometimes a little silver or iron.

Pyr.-Decrepitates in the closed tube. In the open tabe gives selenous fumes aud a red sublimate. B.B. on charcoal a strong selenous odor; partially fuses. Coats the coal near the assay at first gray, with a reddish border (selenium), and later yellow (lead oxide'; ; when pure entirely volatile; with soda gives a globule of metallic lead.

Obs.-Much resembles a granular galenite; but the faint tinge of blue and the B.B selenium fumes serve to distinguish it.

Found at Clausthal, Tilkerode, Zorge, Lehrbach, etc., in the Harz; at Reiusberg in Sax. ony; at the Rio Tinto mines, Spain; Cacheuta mine, Mendoza, S. A.

Zorgite and Lemrbachite occur with clausthalite in the Harz. Zorgite is a lead-copper selenide. Lehrbachite is a lead-mercury selenide.

Berzelianite.- $\mathrm{Cu}_{2} \mathrm{Se}=$ Selenium $38 \cdot 4$, copper $61 \cdot 6=100$. Color silver-white. From Sweden, also the Harz.
altaite.-Composition $\mathrm{PbTe}=$ Tellurium $38 \cdot 3$, lead $61 \cdot 17$. Isometric. Color tin-white. Trom Savodinski in the Altai ; Stanislaus mine, Cal.; Red Cloud mine, Colorado; Province of Coquimbo, Chili.

Tiemannite (Selenquecksilber, Germ.).-A mercury selenide, probably HgSe. Massive. Found in the Harz; also California.

## BORNITE. Erubescite. Purple Copper Ore. Buntkupfererz, Germ.

Isometric. Cleavage : octahedral in traces. Massive, structure granular or compact.
H. $=3$. G. $=4 \cdot 4-5 \cdot 5$. Lustre metallic. Color between copper-red and pinchbeck-brown; speedily tarnishes. Streak pale grayish-black, slightly shining. Fracture sinall conchoidal, uneven. Brittle.

Comp.-For crystallized varieties $\mathrm{FeCu}_{3} \mathrm{~S}_{3}$, or sulphur 28.06, iron $16 \cdot 36$, copper $55 \cdot 58=100$. Other varieties are: $\mathrm{Fe}_{2} \mathrm{Cu}_{3} \mathrm{~S}_{4}, \mathrm{FeCu}_{5} \mathrm{~S}_{3}$, and so on. The ratio of $\mathrm{R}(\mathrm{Cu}$ or Fe$)$ to S has the values $5: 4,4: 3,3: 2,7: 3$ (Rammelsberg). Analysis, Collier, from Bristol, Ct. Sulphur $25 \cdot 83$, copper $61 \cdot 79$, iron $11 \cdot 77$, silver $\mathrm{tr} .=99 \cdot 39(\mathrm{R}: \mathrm{S}=3: 2)$.

Pyr., etc.-In the closed tube gives a faint sublimate of sulphur. In the open tube yields sulphurous oxide, but gives no sublimate. B. B. on charcoal fuses in R.F. to a brittle magnetic globule. The roasted mineral gives with the fluxes the reactions of iron and copper, and with soda a metallic globule. Soluble in nitric acid with separation of sulphur.
Diff.-Distinguished by its copper-red color on the fresh fracture.
Obs.-Found in the mines of Cornwall; at Ross Island in Killarney, Ireland ; at Mount Catini, Tuscany; in the Mansfeld district, Germany; and in Norway, Siberia, Silesia, and Hungary. It is the principal copper ore at some Chilian mines; also common in Peru, Bolivia, and Mexico. At Bristol, Conn., it has been found abundantly in good crystals. Found massive at Mahoopeny, Penn., and in other parts of the same State; also at Chesterfield, Mass. ; also in New Jersey. A common ore in Canada, at the Acton and other mines.
Alabandite (Manganglanz, Germ.). $-\mathrm{MnS}=$ Sulphur $36 \cdot 7$, manganese $63.3=100$. Isometric. Cleavage cubic. Color black. Streak green. From Transylvania, etc.

Grünautri.-A sulphide containing nickel, bismuth, iron, cobalt, copper. From Grünau.

## (b) Blende Group. Isometric; tetrahedral.

## SPHALERITE or ZINC BLENDE. Black-Jack, Engl. Miners.

Isometric: tetrahedral. Cleavage: dodecahedral, highly perfect. Twins twinning-plane 1, as in f. 429. Also botryoidal, and other imitative shapes; sometimes fibrous and radiated; also massive, compact.
$H_{0}=3 \cdot 5-4 . \quad G .=3 \cdot 9-4 \cdot 2 . \quad 4.063$, white, New Jersey. Lustre resinons to adamanite. Color brown, yellow, black, red, green; white or yellow
when pure. Streak white-reddish-brown. Transparent-translicent Fracture conchoidal. Brittle.


Comp., Var.-ZnS =Sulphur 33, zinc $67=100$. But often having part of the zinc replaced by iron, and sometimes by cadmium; also containing in minute quantities, thallium, indium, and gallium. Var. 1. Ordinary. Containing little or no iron; colors white to yellowishbrown, sometimes black; G. $=39-4 \cdot 1$. 2. F'erriferous ; Marmatite. Containing 10 p. c. or more of iron; dark-brown to black; G. $=3 \cdot 9-4 \cdot 2$. The proportion of iron sulphide to zinc sulphide varies from 1:5 to 1:2.3. Cadmiferous; Przibramite. The amount of cadmium present in any blende thus far analyzed is less than 5 per cent. Each of the above varieties may occur (a) in crystals; (b) firm, fibrous, or columnar, at times radiated or plumose ; (c) cleavable, massive, or foliated; ( $($ ) granular, or compact massive.

Pyr., etc.-In the open tube sulphurous fumes, and generally changes color. B.B. on charnoal, in R.F., some varieties give at first a reddish-brown coating of cadmium oxide, and later a coating of zinc oxide, which is yellow while hot and white after cooling. With cobalt solution the zinc coating gives a green color when heated in O.F. Most varieties, after roasting, give with borax a reaction for iron. With soda on charcoal in R.F. a strong green zinc flame. Difficultly fusible.

Dissolves in hydrochloric acid, during which sulphuretted hydrogen is disengaged. Some specimens phosphoresce when struck with a steel or by friction.

Diff.-Generally to be distinguished by its perfect cleavage, giving angles of $60^{\circ}$ and $120^{\circ}$; by its resinous lustre, and also by its infusibility.

Obs.-Occurs in both crystalline and sedimentary rocks, and is usually associated with galenite ; also with barite, chalcopyrite, fluorite, siderite, and frequently in silver mines.

Derbyshire. Cumberland, and Cornwall, afford different varieties; also Transylvania; Hungary ; the Harz; Sahla in Sweden; Ratieborzitz in Bohemia; many Saxon localities. Splendid crystals in dolomite are found in the Binnenthal.

Abounds with the lead ore of Missouri, Wisconsin, Iowa, and Illinois. In N. York, Sullivan Co., near Wurtzboro' ; in St. Lawrence Co., at Cooper's falls, at Mineral Point; at the Ancram lead mine in Columbia Co. ; in limestone at Lockport and other places. In Mass., at Sterling; at the Southampton lead mines; at Hatfield. In $N$. Hamp., at the Eaton lead mine; at Warren, a large vein of black blende. In Maine, at the Lubec lead mines, etc. In Conn., at Roxbury, and at Lane's mine, Monroe. In N. Jersey, a white variety at Franklin. In Penn., at the Wheatley and Perkiomen lead mines; near Friedensville, Lehigh Co. In Virginia, at Austin's lead mines, Wythe Co. In Michigan, at Prince vein, Lake Superior. In Illinois, near Rosiclare ; near Galena, in stalactites, covered with pyrite, and galenite In Wisconsin, at Mineral Point. In Tennesiee, at Haysboro', near Nashville.

Named bilende because, while often resembling galena, it yielded no lead, the word in Ger man meaning blind or leceiving. Sphalerite is from $\sigma \phi a \lambda \epsilon \rho \dot{\rho}$, treacherous.

## (c) Chalcocite Group. Orthorhombic.

## hessite.* Tellursilber, Germ.

Orthorhombic, and resembling chalcocite. Cleavage indistinct. Mas sive ; compact or fine grained ; rarely coarse-granular.
$\mathrm{H} .=2-3 \cdot 5$. G. $=8 \cdot 3-8 \cdot 6$. Lustre metallic. Color between lead-gray and steel-gray. Sectile. Fracture even.

Comp.- $\mathrm{Ag}_{2} \mathrm{Te}=$ Tellurinm $37 \cdot 2$, silver $62 \cdot 8=100$. Silver sometimes replaced in part by gold.

Pyr.-In the open tube a faint white sublimate of tellurous oxide, which B.B. fuses to colorless globules. On charcoal fuses to a black globule ; this treated in R.F. presents on cooling white dendritic points of silver on its surface ; with soda gives a globule of silver.

Obs.-Occurs in the Altai, in Siberia, in a talcose rock ; at Nagyag in Transylvania, and at Retzbanya in Hungary; Stanislaus mine, Calaveras Co., Cal.; Red Cloud mine, Colorado; Province of Coquimbo, Chili.

Petzite.-Differs from hessite in that gold replaces much of the silver. H.=2.5. G. $=$ 8.72-8.83, Petz; $9 \times 9 \cdot 4$, Küstel. Color between steel-gray and iron-black, sometimes with pavonine tarnish. Streak iron-black. Brittle. Analysis by Genth, from Goiden Rule mine, tellurium $32 \cdot 68$, silver $41 \cdot 86$, gold $25 \cdot 60=100 \cdot 14$. Occurs at Nagyag, Stanislaus mine, California, and several localities in Colorado.

Tapalpite (Tellurwismuthsilber).-Composition (Ramm.), $\mathrm{Ag}_{2} \mathrm{Bi}_{2} \mathrm{Te}_{2} \mathrm{~S}\left(\mathrm{Ag}_{2} \mathrm{~S}+2 \mathrm{BiTe}\right.$ ). Granular. Color gray. Sierra de Tapalpa, Mexico.

## ACANTHITE.

Urthorhombic. $I \wedge I=110^{\circ} 54^{\prime} ; ~ O \wedge 1-\bar{\imath}=124^{\circ} 42^{\prime}$, Dauber $; ~ c: \bar{b}: d$ $=1 \cdot 4442: 1 \cdot 4523: 1 . \quad O \wedge 1-\check{\iota}=135^{\circ} \quad 10^{\prime} ; \quad 0 \wedge 1=119^{\circ} 42^{\prime}$. Twins: parallel to $1-\bar{i}$. Crystals usually slender-pointed prisms. Cleavage indistinct.
$\mathrm{H} .=2 \cdot 5$ or under. G. $=7 \cdot 16-7 \cdot 33$. Lustre metallic. Color iron-black or like argentite. Fracture uneven, giving a shining surface. Sectile.

Comp.- $\mathrm{Ag}_{2} \mathrm{~S}$, or like argentite. Sulphur $12 \cdot 9$, silver $87 \cdot 1=100$.
Pyr.-Same as for argentite, p. 235.
Obs.-Found at Joachimsthal; also near Freiberg in Saxony.
CHALCOCITE. Chalcosine. Vitreous Copper. Copper Glance. Kupferglanz, Germ. $1.7176: 1 ; O \wedge 1=117^{\circ} 24^{\prime} ; O \wedge 1-\breve{\imath}=135^{\circ} 52^{\prime}$. Cleavage: $I$, indistinct. Twins: twinning-plane, $I$, producing hexagonal, or stellate forms (left half

of f .432 ) ; also $\frac{4}{3}-\check{2}$, a cruciform twin (f. 432), crossing at angles of $111^{\circ}$ and $69^{\circ}$; f. 433, a cruciform twin, having $O$ and $I$ of one crystal parallel respectively to $i-\imath$ and $O$ of the other. Also massive, structure granular, or compact and impalpable
H. $=2 \cdot 5-3$. G. $=5 \cdot 5 \cdot 5-5 \cdot 8$. Lustre metallic. Color and streak blackish lead-gray ; often tarnished blue or green ; streak sometimes shining. Fracture conchoidal.

Comp. $-\mathrm{Cu}_{2} \mathrm{~S}=$ Sulphur $20 \cdot 2$, copper $79 \cdot 8=100$.
Pyr., etc.-Yields nothing volatile in the closed tube. In the open tube gives off sulphurous fumes. B.B. on charcoal melts to a globule, which boils with spirting; with soda is reduced to metallic copper. Soluble in nitric acid.

Obs.-Cornwall affords splendid crystals. The compact and massive varieties occur in Siberia, Hesse, Saxony, the Banat, etc. ; Mt. Catini mines in Tuscany; Mexico, Peru, Bolivia, Chili.

In the United States, it has been found at Bristol, Conn., in large and brilliant crystals. In Virginia, in the United States copper mine district, Orange Co. Between Newmarket and Taneytown, Maryland. In Arizona, near La Paz ; in N. W. Sonora. In Nevada, in Washoe, Humboldt. Churchill, and Nye Cos.

Harrisite of Shepard, from Canton mine, Georgia, is chalcocite with the cleavage of galenite (pseudomorphous, (Fenth).

STROMEYERITE. Silberkupferglanz, Germ.
Orthorhombic: isomorphous with chalcocite. $I \wedge I=119^{\circ} 35^{\prime}$. Also massive, compact.
$\mathrm{H} .=2 \cdot 5-3 . \quad \mathrm{G} .=6 \cdot 2-6.3$. Lustre metallic. Color dark steel-gray. Streak shining. Fracture subconchoidal.

Comp $-\mathrm{AgCuS}=\mathrm{Ag}_{2} \mathrm{~S}+\mathrm{Cu}_{2} \mathrm{~S}=$ Sulphur $15 \cdot 7$, silver $53 \cdot 1$, copper $31 \cdot 2=100$.
Pyr., etc.-Fuses, but gives no sublimate in the closed tube. In the open tube sulphurous fumes. B.B. on charcoal in O.F. fuses to a semi-malleable globule, which, treated with the fluxes, reacts strongly for copper, and cupelled with lead gives a silver globule. Soluble in nitric acid.

Obs.-Found at Schlangenberg, in Siberia ; at Rudelstadt, Silesia ; also in Chili ; at Combavalla in Peru; at Heintzelman mine in Arizona.


## (d) Pyrrhotite Group. Hexagonal.

## X cinnabar. Zinnober, Germ.

Rhombohedral. $R \wedge R=92^{\circ} 36^{\prime}, R \wedge O=127^{\circ} 6^{\prime} ; \dot{c}=1 \cdot 1448$. A $G^{-}$ cording to DesCloizeaux, tetartohedral, like quartz.

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 Also granular, massive ; sometimes forming superficial coatings.

Cleavage: $I$, very perfect. Twins: twinning. plane $O$.
$\mathrm{H}=2-2 \cdot 5 . \quad \mathrm{G}=8 \cdot 998$, a cleavable variety from Neumarktel. Lustre adamantine, inclining to metallic when dark-colored, and to dull in friable varieties. Color cochineal-red, often inclining to brownish-red and lead-gray. Streak scarlet, subtransparent, opaque. Fracture subcouchridal. un even. Sectile. Polarizaticu circular.

Comp. $-\mathrm{HgS}_{\mathrm{Hg}}$ (or $\mathrm{Hg}_{3} \mathrm{~S}_{3}$ ) $=$ Sulphur 13.8 , mercury $86 \cdot 2=100$. Sometimes impurt from clay. tron sesquioxide, bitumen.

Pyr.-In the closed tube a black sublimate. Carefully heated in the open tube gives sul phurous fumes and metallic mercury, condensing in minute globules on the cold walls of the tube. B.B. on charcoal wholly volatile if pure.

Obs.-Cinnabar occurs in beds in slate rocks and shales, and rarely in granite or porphyry. It has been observed in veins, with ores of iron. The most important European beds of this ore are at Almaden in Spain, and at Idria in Carniola. It occurs at Reichenau and Windiseh Kappel in Carinthia; in Transylvania; at Ripa in Tuscany; at Schemnitz in Hungary; in the Urals and Altai ; in China abundantly, and in Japan ; San Onofre and elsewhere in Mexico; in Southern Peru; forming extensive mines in California, in the coast ranges the principal mines are at New Almaden and the vicinity, in Santa Clara Co. Also in Idaho, in limestone, ajoundant.

This ore is the source of the mercury of commerce, from which it is obtained by sublima tion. When pure it is identical with the manufactured vermilion of commerce.

Metacinvabarite (Moore).-A black mercury sulphide (HgS). Rarely crystallize.ö $\mathrm{H}_{\mathrm{H}}=3$. G. $=7 \cdot \%$. Lustre metallic. Redington mine, Lake Co., Cal.

Guadalcazarite.-Essentially HgS, with part ( $\left(\frac{1}{35}\right)$ of the sulphur replaced by selenium, and part of the mercury replaced by zinc ( $\mathrm{Hg}: \mathrm{Zn}=6: 1$, Petersen ; $=12: 1$, Ramm.). Massive. Color deep black. Guadalcazar, Mexico. Leviglianite is a ferruginous variety from Levigliani, Italy.

MILLDRITE.* Capillary Pyrites. Haarkies; Nickelkies, Germ.
Rhombohedral. $R \wedge R=144^{\circ} 8^{\prime}$, Miller. $\dot{c}=0.32955$. O $\wedge R=159^{\circ} 10^{\prime}$.
Clearage: rhombohedral, perfect. Usual in capillary crystals. Also in columuar tufted coatings, partly semi-globular and radiated.
$\mathrm{H} .=3-3 \cdot 5$. G. $=4 \cdot 6-5 \cdot 65$. Lustre metallic. Color brass-yellow, inclining to bronze-yellow, with often a gray iridescent tarnish. Streak bright. Brittle.

Comp. -NiS =Sulphur 35 6, nickel $64 \cdot 4=100$.
Pyr., etc.-In the open tube sulphurous fumes. B. B. on charcoal fuses to a globule. When roasted, gives with borax and salt of phosphorus a violet bead in O.F., becoming gray in R.F. from reduced metallic nickel. On charcoal in R.F. the roasted mineral gives a coherent metallic mass, attractable by the magnet. Soluble in nitric acid.

Obs.-Found at Joachimsthal ; Przibram; Riechelsdorf; Andreasberg; several localities in Saxony; Coruwall.

Occurs at the Sterling mine, Antwerp, N. Y. ; in Lancaster Co., Pa., at the Gap mine ; with dolomite, and penetrating calcite crystals, in cavities in limestone, at St. Louis, Mo.

Beyrichite (Liebe). -Formula $\mathrm{Ni}_{3} \mathrm{~S}_{7}=$ Sulphur $43 \cdot 6$, nickel $56 \cdot 4=100$. Color lead-gray. Occurs in radiated groups with millerite in the Westerwald.

PYRRHOTITE. Magnetic Pyrites. Magnetkies, Germ.
Hexagonal. $O \wedge 1=135^{\circ} 8^{\prime} ; \dot{c}=0.862$. Twins: twinning-plane 1 (f.435). Cleavage: $O$, perfect; $I$, less so. Commonly massive and amorphous; structure granular.
$\mathrm{H} .=3 \cdot 5-4 \cdot 5 . \quad \mathrm{G} .=4 \cdot 4-4 \cdot 68$. Lustre metallic. Color between bronze-yellow and copper-red, and subject to speedy tarnish. Streak dark grayishblack. Brittle. . Magnetic, being attractable in tine powder by a magnet, even when not affecting an ordinary needle.


Comp.- (1) Mostly $\mathrm{Fe}_{7} \mathrm{~S}_{8}=$ Sulphur $39 \cdot 5$, iron $60 \cdot \widetilde{5}=100$; but varying to $\mathrm{Fe}_{8} \mathrm{~S}_{9}, \mathrm{Fe}_{9} \mathrm{~S}_{10}$ and $\mathrm{Fe}_{10} \mathrm{~S}_{11}$. Some varieties contain 3-6.p. c. nickel. Horbachite contains (Wagner) 12 p. c. Ni.
Pyr., etc.-Unchanged in the closed tube. In the open ture gives sulphurous ozide. On
charcoal in R.F. fuses to a black magnetic mass; in O.F. is converted into iron sesquivxide, which with fluxes gives only an iron reaction when pure, but many varieties yield small amounts of nickel and cobalt. Decomposed by muriatic acid, with evolution of sulphuretted hydrogen.
Diff.-Distinguished by its magnetic character, and by its bronze color on the fresh fracture.
Obs.-Occurs in Norway ; in Sweden; at Andreasberg; Bodenmais in Bavaria; N. Tagilsk; in Spain; the lavas of Vesuvius; Cornwall.

In N. America, in Vermont, at Stafford, Corinth, and Shrewsbury ; in many parts of Massachusetts; in Connecticut, in Trumbull, in Monroe; in N. York, near Natural Bridge in Diana, Lewis Co.; at O'Neil mine and elsewhere in Orange Co. In N. Jersey, Morris Co., at Hurdstown. In Pennsylvania, at the Gap mine, Lancaster Co., niccoliferous. In Tennes* see, at Ducktown mines. In Canada, at St. Jerome; Elizabethtown, Ontario (f. 435), etc.

The niccoliferous pyrrhotite is the ore that affords the most of the nickel of commerce.
Trorlite.-According to the latest investigations of J. Lawrence Smith, composition FeS, iron proto-sulphide ; that is, iron $63 \cdot 6$, sulphur $36 \cdot 4=100$. Occurs only in iron meteorites. Daubréelite (Smith). -Composition $\mathrm{Cr}_{2} \mathrm{~S}_{3}$. Observed in the meteoric iron of Northern Mexico; occurring on the borders of troilite nodules. Similar to shepardite, Haidinger (=schreibersite, Shepard), described by Shepard (1846) as occurring in the Bishopville, S. C., meteoric iron.

Schreibersite also solely a meteoric mineral. Contains iron, nickel, and phosphorus.
WUrtzite (Spiauterite).-ZnS, like sphalerite, but hexagonal in crystallization. Bolivia.

## GREENOCKITE.

Hexagonal; hemimorphic. $O \wedge 1=136^{\circ} 24^{\prime} ; \dot{c}=0.8247$. Cleavage: $I$, distinct; $O$, imperfect.
$\mathrm{H} .=3-3 \cdot 5$. G. $=4 \cdot 8-4 \cdot 999$. Lustre adamantine. Color honey-yellow; citron-yellow; orange-yellow-veined parallel with the axis; bronzeyellow. Streak-powder between orange-yellow and brick-red. Nearly transparent. Strong double refraction. Not thermoelectric, Breithaupt.

Comp.-CdS (or $\mathrm{Cd}_{3} \mathrm{~S}_{3}$ ) = Sulphur 22•2, cadium 77.8.
Pyr., etc.-In the closed tube assumes a carmine-red color while hot, fading to the original yellow on cooling. In the open tube gives sulphurous oxide. B.B. on charcoal, either alone or with soda, gives in R.F. a reddish-brown coating. Soluble in hydrochloric acid, evolving sulphuretted hydrogen.

Obs.-Occurs at Bishoptown, in Renfrewshire, Scotland; also at Przibram in Bohemia; on sphalerite at the Ueberoth zinc mine, near Friedensville. Lehigh Co., Pa., and at Granby, Mo.

## NICCOLITE. Copper Nickel. Kupfernickel, Rothnickelkies, Germ.

Hexagonal. $O \wedge 1=13^{\circ} 635^{\prime} ; \dot{c}: 0 \cdot 81944$. Usually massive, structure nearly impalpable; also reniform with a columnar structure ; also reticulated and arborescent.
H. $=5-5 \cdot 5$. G. $=7 \cdot 33-7 \cdot 671$. Lustre metallic. Color pale copper-red, with a glay to blackish tarnish. Streak pale brownish-black. Opaque. Fracture uneven. Brittle.

Comp.-NiAs (or $\mathrm{Ni}_{3} \mathrm{As}_{3}$ ) $=$ Arsenic $56 \cdot 4$, nickel $43 \cdot 6=100$; sometimes part of the arsenic replaced by antimony.
Pyr., etc.-In the closed tube a faint white crystalline sublimate of arsenous oxide. In the open tube arsenous oxide, with a trace of sulphurous oxide, the assay becoming yellowishgreen On charcoal gives arsenical fumes and fuses to a globule, which, treated with borax glass, affords, by successive oxidation, reactions for iron, cobalt, and nickel. Soluble in nitro-hydrochloric acid.

Diff-Distinguished by its color from other similar sulphides, as also by its pyrognostics.

Obs.-Occurs at several Saxon mines, also in Thuringia, Hesse, and Styria, and at Alle. inont in Dauphiny; occasionally in Cornwall; Chili ; abundant at Mina de la Rioja, in the Argentine Provinces. Found at Chatham, Conn., in gneiss, associated with smaltite.

Breithauptite.-Composition NiSb=Antimony $67 \cdot 8$, mickel $32 \cdot 2=100$. Color light copper-red. Andreasberg.

Arite -As antimoniferous niccolite, containing 28 p. c. Sb. Basses-Pyrenées; Wolfach, Baden.

## C. DEUTO or PYRITE DIVISION.

(a) Pyrite Group.

PYRITE.* Iron Pyrites. Schwefelkies, Eisenkies, Germ.

Isometric ; pyritohedral. The cube the most common form ; the pyrito${ }^{\prime}$ 'iedron, f. 92 , p. 23, and related forms, f. $94,95,96$, also very common. See also f. 103, 104, 105, p. 24. Cubic faces often striated, with striations of adjoining faces at right angles, and due to oscillatory combination of the cube and pyritohedron, the strize having the direction of the edges between $O$ and $i-2$. Crystals sometimes acicular through elongation of cubic and other forms. Cleavage: cubic and octahedral, more or less distinct. Twins: twining-plane $\bar{I}$, f. 276, p. 93 . Also reniform, globular, stalactitic, with a crystalline surface; sometimes radiated subfibrous. Massive.

$\mathrm{H} .=6-6.5$. G. $=4 \cdot 83-5 \cdot 2$. Lnstre metallic, splendent to glistening. Color a pale brass-yellow, nearly uniform. Streak greenish or brownishblack. Opaque. Fracture conchoidal, uneven. Brittle. Strikes fire with steel.

Comp., Var. $-\mathrm{FeS}_{2}=$ Sulphur $53 \cdot 3$, iron $46 \cdot 7=100$. Nickel, cobalt, and thallium, and also copper, sometimes replace a little of the iron, or else occur as mixtures; and gold is sometimes present, distributed invisibly through it.

Pyr., etc.-In the closed tube a sublimate of sulphur and a magnetic residue. B.B. on charcoal gives off sulphur, burning with a blue flame, leaving a residue which reacts like pyrrhotite. Insoluble in hydrochloric acid, but decomposed by nitric acid.
Diff.-Distinguished from chalcopyrite by its greater hardness, since it cannot be cut with a knife; as also by its pale color; from marcasite by its specific gravity and color. Not malleable like gold

Obs.-Pyrite occurs abundantly in rocks of all ages, from the oldest crystalline rocks to the
most recent alluvial deposits. It usually occurs in small cubes, also in irregular sphervidal nodules and in veins, in clay slate, argillaceous sandstones, the coal formation, etc. The Cornwall mines, Alston-Moor, Derbyshire, Fahlun in Sweden, Kongsberg in Norway, Elba, Traversella in Piedmont, Peru, are well-known localities.

Occurs in New England at many places: as the Vernon slate quarries; Roxbury, Conn., etc. In N. York, at Rossie, at Schoharie; in Orange Co., at Warwick and Deerpark, and many other places. In Pennsylvania, at Little Britain, Lancaster Co. ; at Cbester, Delaware Co.; in Carbon, York, and Chester Cos. ; at Cornwall, Lebanon Co., etc. In Wisconsin, near Mineral Point. In N. Car., near Greensboro', Guilford Co. Auriferous pyrite is common at the mines of Colorado, and many of those of California, as well as in Virginia and the States south.

This species affords a considerable part of the iron sulphate and sulphuric acid of commerce and also much of the sulphur and alum. The auriferous variety is worked for gold in many gold regions.
The name pyrite is derived from $\pi \grave{o}$, fire, and alludes to the sparks from friction.
Haderite.-Composition $\mathrm{MnS}_{2}=$ Sulphur 53•7, manganese $46 \cdot 3=100$. Isometric. Color reddish-brown. Kalinka, Hungary.

## $\Varangle$ Chalcopyrite.* Copper Pyrites. Kupferkies, Germ.

Tetragonal ; tetrahedral. $O \wedge 1-i=135^{\circ} 25^{\prime} ; \dot{c}=0.98556 ; O \wedge 1=125^{\circ}$ $40^{\prime} ; 1 \wedge 1$, pyr., $=109^{\circ} 53^{\prime} ; 1 \wedge 1$ (f. 440 ) $=71^{\circ} 20^{\prime}$ and $70^{\circ} 7^{\prime}$. Cleavage: $2-i$ sometimes distinct; $O$, indistinct. Twins: twimning-plane $1-i$; the plane 1 (see p. 94). Often massive.

H. $=3 \cdot 5-4$. G. $=4 \cdot 1-4 \cdot 3$. Lustre metallic. Color brass-yellow ; subject to tarnish, and often iridescent. Streak greenish-black-a little shining. Opaque. Fracture conchoidal, uneven.

Comp.-CuFeS ${ }_{2}=$ Sulphur $34 \cdot 9$, copper $34 \cdot 6$, iron $30 \cdot 5=100$. Some analyses give otber proportions; but probably from mixture with pyrite. There are indefinite mixtures of the two, and with the increase of the latter the color becomes paler.

This species, although tetragonal, is very closely isomorphous with pyrite, the variation from the cubic form being slight, the vertical axis being 0.98556 instead of 1 .

Traces of selenium have been noticed by Kersten in an ore from Reinsberg near Freiberg. Thallium is also present in some kinds, and more frequently in this ore than in pyrite.

Pyr., etc. -In the closed tube decrepitates, and gives a sulphur sublimate; in the open tabe sulphurous oxide. B.B. on charcoal gives sulphur fumes and fuses to a magnetic glo bule. The roasted ore reacts for copper and iron with the fluxes; with soda on charcoal gives a globule of metallic iron with copper. Dissolves in nitric acid, excepting the sulphur, and forms a green solution; ammonia in excess changes the green color to a deep blue.

Diff.-Distinguished from pyrite by its inferior hardness, it can be easily scratched with the knife ; and by its deeper color. Not malleable like gold, from which it differs also in being decomposed by nitric acid.

Obs.-Chalcopyrite is the principal ore of copper at the Cornwall mines. Occurs at Frel verg; in the Bannat; Hungary ; and Thuringia ; in Scotland ; in Tuscany ; in South Australia; in fine crystals at Cerro Blanco, Chili.

A cominon mineral in America, some localities are: Stafford, Vt. ; Rossie, Ellenville, N. Y.; Phenixville, etc., Penn. The mines in North Carolina and eastern Tennessee afford large quantities. Occurs in Cal., in different mines along a belt between Mariposa Co. and Del Nort Co., on west side of, and parallel to, the chief gold belt; occurring massive in Calaveras Co.; in Mariposa Co, etc. In Canada, in Perth and near Sherbrooke; extensively mined at Bruce mines, on Lake Huron.
Named from $\chi$ a入kis, brass. and pyrites, by Henckel, who observes in his Pyritology (1\%25) that chalcopyrite is a good distinctive name for the ore.
Cubantte is $\mathrm{CuFe}_{2} \mathrm{~S}_{4}$, or $\mathrm{CuFe}_{2} \mathrm{~S}_{3}$ (Scheidhauer).-Occurs massive at Barracanao, Cuba; T'unaberg, Sweden.

Barnilardtite, from North Carolina.-Composition uncertain, perhaps $\mathrm{Cu}_{4} \mathrm{Fe}_{2} \mathrm{~S}_{5}$. It may be partly altered from chalcopyrite.

Stannite (Zinnkies, Germ.).-A sulphide containing 26 p . c. tin; also copper, iron, and zinc. Massive. Color steel-gray. Chiefly from Cornwall, also Zinnwald.

## LINNEITTE. Kobaltnickelkies, Germ.

Isometric. Cleavage: cubic, imperfect. Twins: twinning-plane octahedral. Also massive, granular to compact.
H. $=5 \cdot 5$. G. $=4 \cdot 8-5$. Lustre metallic. Color pale steel-gray, tarnishing copper-red. Streak blackish-gray. Fracture uneven or subconchoidal.

Comp- $-\mathrm{Co}_{3} \mathrm{~S}_{4}$ (or $2 \mathrm{CoS}+\mathrm{CoS}_{2}$ )=Sulphur $42 \cdot 0$, cobalt $58.0=100$; but having the cobalt replaced partly by nickel or copper, the proportions varying very much. The Müsen ore (siegenite) contains 30-40 p. c. of nickel.
Pyr., etc - The variety from Miusen gives, in the closed tube, a sulphur sublimate; in the open tube, sulphurous fumes, with a faint sublimate of arsenous oxide. B.B. on charcoal gives arsenical and sulphurous odors, and fuses to a magnetic globule. The roasted mineral gives with the fluxes reactions for nickel, cobalt, and iron. Soluble in nitric acid, with separation of sulphur.
Diff.-Distinguished by its color, and isometric crystallization.
Ob.3.--In gneiss, at Bastnaes, Sweden; at Müsen, near Siegen, in Prussia; at Siegen (sicgenite), in octahedrons; at Mine la Motte, in Missouri, mostly massive, also crystalline • and at Mineral Hill, in Maryland.

## SMALTITE.* Speiskobalt, Germ.

Isometric. Cleavage : octahedral, distinct ; cubic, in traces. Also massive and in reticulated and other imitative shapes.
$\Pi .=5 \cdot 5-6 . \quad$ G. $=6 \cdot 4$ to $7 \cdot 2$. Lustre metallic. Color tin-white, inclining, when massive, to steel-gray, sometimes iridescent, or grayish from tarnish. Streak grayish-black. Fracture granular and uneven. Brittle.

Comp., Var.-For typical kind ( $\mathrm{Co}, \mathrm{Fe}, \mathrm{Ni}$ ) $\mathrm{As}_{2}=$ (if $\mathrm{Co}, \mathrm{Fe}$, and Ni be present in equal parts) Arsenic $72 \cdot 1$, cobalt $9 \cdot 4$, nickel $9 \cdot 5$, iron $9 \cdot 0=100$. It is probable that nickel is never wholly absent, although not detected in some of the earlier analyses; and in some kinds it is the principal metal. The proportions of cobalt, nickel, and iron vary much.
The following analyses will serve as examples of the different varieties:

|  | As | Co | Ni | Fe | Cu |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 1. Schneeberg | $70 \cdot 37$ | 18.95 | $1 \cdot 79$ | $11 \cdot 71$ | $1 \cdot 39$ | 0.66, $\mathrm{Bi} 0.01=99.88$ Hofmann |
| 2. Allemont (chloanthite) | $71 \cdot 11$ |  | 18.71 | 6.82 |  | $2 \cdot 29=98.93$ |
| \%. Riechelsdorf | $60 \cdot 42$ | $10 \cdot 80$ | 25.87 | $0 \cdot 80$ |  | S $2 \cdot 11=100$. |
| 4. Schneeberg | 74.80 | 3.79 | $12 \cdot 86$ | $7 \cdot 33$ |  | S $0.85=99.63$ Karsted |

Pyr., etc.-In the close tube gives a sublimate of metallic arsenic; in the open tube a white sublimate of arsenous oxide, and sometimes traces of sulphurous oxide. B.B. on charcoal gives an arsenical odor, and fuses to a globule, which, treated with successive portions of borax-glass, affords reactions for iron, cobalt, and nickel.

Obs.-Usually occurs in veins, accompanying ores of cobalt or nickel, and ores of silver and copper ; also, in some instances, with niccolite and arsenopyrite; often having a coating of anuabergite.
Occurs at Schneeberg, etc., in Saxony ; at Joachimsthal ; also at Wheal Sparnon in Corn. wall; at Riechelsdorf in Hesse; at Tunaberg in Sweden; Allemont in Dauphiné. Alge in crystals at Mine La Motte, Missouri. At Chatham, Conn., the chloanthite (chathamite) uccurs in mica slate, associated generally with arsenopyrite and sometimes with niccolite.

Spathiopyrite is closely allied to smaltite, with which it occurs at Bieber in Hessen.
SKUTTERUDITE (Tesseralkies, (ferm.).-CoAs $=$ Arsenic 79 ${ }^{\circ}$, cobalt $20.8=100$. Isometric. Skutterud, Norway.

## COBALTITE. Glance Cobalt. Kobaltglanz, Germ.

Isometric ; pyritohedral. Commonly in pyritohedrons (f. 92, 95, etc., p. 23). Cleavage: cubic, perfect. Planes $O$ striated. Also massive, granular or compact.
$\mathrm{H} .=5 \cdot 5$. G. $=6-6 \cdot 3$. Lustre metallic. Color silver-white, inclined to red; also steel-gray, with a violet tinge, or grayish-black when containing much iron. Streak grayish-black. Fracture uneven and lamellar. Brittle.

Comp., Var.-CoAsS (or $\mathrm{CoS}_{2}+\mathrm{CoAs}_{2}$ ) = Sulphur $19 \cdot 3$, arsenic $45 \cdot 2$, cobalt $35 \cdot 5=100$. The cobalt is sometimes largely replaced by iron, and sparingly by copper.

Pyr., etc.-Unaltered in the closed tube. In the open tube, gives sulphurous fumes and a crystalline sublimate of arsenous oxide. B.B. on charcoal gives off sulphur and arsenic, and fuses to a magnetic globule ; with borax a cobalt-blue color. Soluble in warm nitric acid, separating arsenous oxide and sulphur.

Diff.-Distinguished by its reddish-white color; also by its pyritohedral form.
Obs.-Occurs at Tunaberg, Hokansbö, in Sweden; also at Skutterud in Norway. Other localities are at Querbach in Silesia, Siegen in Westphalia, and Botallack mine, in Cornwall. The most productive mines are those of Vena in Sweden.
This species and smaltite afford the greater part of the smalt of commerce. It is also employed in porcelain painting.

GERSDORFFITE. Nickelarsenikkies, Arseniknickelglanz, Germ.
Isometric : pyritohedral. Cleavage: cubic, rather perfect. Also lamellar and granular massive.
$\mathrm{H} .=5 \cdot 5$. G. $=5.6-6 \cdot 9$. Lustre metallic. Color silver-white-steelgray, often tarnished gray or grayish-black. Streak grayish-black. Fracture uneven.

Comp., Var.-Normal, NiAsS (or $\mathrm{NiS}_{2}+\mathrm{NiAs}_{2}$ ) $=$ Arsenic $45 \cdot 5$, sulphur $19 \cdot 4$, nickel $35 \cdot 1=$ 100. The composition varies in atomic proportions rather widely.

Pyr., etc.-In the closed tube decrepitates, and gives a yellowish-brown sublimate of arsenic sulphide. In the open tube yields sulphurous fumes, and a white sublimate of arsenous oxide. B.B. on charcoal gives sulphurous and garlic odors and fuses to a globule, which, with borax-glass, gives at first an iron reaction, and, by treatment with fresh portions of tho flux, cobalt and nickel are successively oxidized.
Decomposed by nitric acid, forming a green solution, with separation of sulphur and arsenous oxide.

Obs.-Occurs at Loos in Sweden; in the Harz; at Schladming in Styria; Kamsdorf in Lower Thuringia; Haueisen, Voigtland; near Ems. Also found as an incrustation at Phenixville, Pa.

Ullmannite. - NiSbS $\left(\mathrm{NiS}_{2}+\mathrm{NiSb}_{2}\right)=$ Antimony $57 \cdot 2$, sulphur $15 \cdot 1$, nickel $27 \cdot 7=100$ Generally contains also some arsenic. Color steel-gray. Siegen, Harzgerode, etc.

Corynite. - Ni(As, Sb ) S , but the arsenic ( 38 p. c.) in excess of the antimony. Olsa, Corinthia. Wolfachite (Petersen), from Wolfach, Baden, is similar in composition, but is orthorhombic in form.

LaURITE.-An osmium-ruthenium sulphide. Analysis (Wöhler) Sulphur 31•79 [Osmians 3.03], Ruthenium $65.18=100$. Occurs in minute octahedrons from the platinum-washi igs of Borneo ; as also those in Oregon.

## (b) Marcasite Group. Orthorhombic.

## MARCASITE. White Iron Pyrites. Strahlkies, etc., Germ.

Urthorhombic. $\quad I \wedge I=106^{\circ} 5^{\prime}, O \wedge 1-\bar{\imath}=122^{\circ} 26^{\prime}$, Miller ; $\dot{c}: \bar{b}: a=$ $1.5737: 1 \cdot 3287: 1 . \quad O \wedge 1=116^{\circ} 55^{\prime} ; O \wedge 1-乞$
$=130^{\circ} 10^{\prime}$. Cleavage : $I$ rather perfect ; 1- $\check{\imath}$ in traces. Twins: twinning-plane 1, sometimes consisting of five individuals (see f. 308, p. 98) ; also $1-\bar{\imath}$. Also globular, reniform, and other imitative shapes-structure straight columnar;
 oftell massive, colummar, or granular.
$\mathrm{H} .=6-65$. G. $=4 \cdot 678-4 \cdot 847$. Lustre metallic. Color pale bronze-yellow, sometimes inclined to green or gray. Streak grayish- or brownishblack. Fracture uneven. Brittle.

Comp., Var.--FeS 2 , like pyrite=Sulphur $53 \cdot 3$, iron $46 \cdot 7=100$.
The varieties that have been recognized depend mainly on state of crystallization; as the Radiated (Strallkies): Radiated; also the simple crystals. (Cockscomb (Kammkies) : Aggregations of flattened crystals into crest-like forms. Spear (Speerkies): Twin crystals, with reëntering angles a little like the head of a spear in form. Capillary (IIaarkies): In capillary crystallizations, etc.

- Pyr.-Like pyrite. Very liable to decomposition; more so than pyrite.

Diff.-Distinguished from pyrite by its paler color, especially marked on a fresh surface; by its tendency to tarnish; by its inferior specific gravity.

Obs.-Occurs near Carlsbad in Bohemia; at Joachimsthal, and in several parts of Saxony ; in Derbyshire; near Alston Moor in Cumberland; near Tavistock in Devonshire, and in Cornwall.

At Warwick, N. Y. Massive fibrous varieties abound throughout the mica slate of New Ergland, particularly at Cummington, Mass. Occurs at Lane's mine, in Monroe, Conn. ; in Trumbull; at East Haddam ; at Haverhill, N. H. ; Galena, Ill., in stalactites. In Canada in Neebing.

Marcasite is employed in the manufacture of sulphur, sulphuric acid, and iron sulphate, though less frequently than pyrite.

ARSENOPYRITE, or MISPICKEL. Arsenical Pyrites. Arsenikkies, Germ.
Orthorhombic. $I \wedge I=111^{\circ} 53^{\prime}, O \wedge 1-\bar{\imath}=119^{\circ} 37^{\prime} ; \dot{c}: \bar{b}: \breve{a}=17588$ : 1•4793:1. $\quad 0 \wedge 1=115^{\circ} 12^{\prime}, O \wedge 1-\varkappa=130^{\circ} 4^{\prime}$. Cleavage: $I$ rather distinct ; $O$, faint traces. Twins: twinning-plane $I$, and $1 \cdot \bar{i}$. Also columnar, straight and divergent ; granular, or compact.
$\mathrm{H} .=5 \cdot{ }^{2}-6 . \quad \mathrm{G} .=6 \cdot 0-6 \cdot 4 ; 6 \cdot 269$, Franconia, Kenngott. Lustre metallia

Color silver-white, inclining to steel-gray. Streak dark grayish-black. Frac ture uneven. Brittle.


Comp., Var.-FeAsS $=\mathrm{FeS}_{2}+\mathrm{FeAs}_{2}=$ Arsenic $46 \cdot 0$, sulphur 19.6, iron $34 \cdot 4=100$. Part of the iron sometimes replaced by cobalt; a little nickel. bismuth, or silver are also occasionally present. The cobaltic variety, called danaite (after J. Freeman Dana), contains 4-10 p. c. of cobalt.

Pyr., etc.-In the closed tube at first gives a red sublimate of arsenic sulphide, then a black lustrous sublimate of metallic arsenic. In the open tube.gives sulphurous fumes and a white sublimate of arsenous oxide. B.B. on charcoal gives the odor of arsenic. The varieties containing cobalt give a blue color with borax-glass when fused in O.F. with successive portions of flux until all the iron is oxidized. Gives fire with steel, emitting an alliaceous odor. Decomposed by nitric acid with separation of arsenous oxide and sulphur.

Diff.-Distinguished by its form from smaltite. Leucopyrite (löllingite) do not give decided sulphur reactions.
Obs.-Found principally in crystalline rocks, and its usual mineral associates are ores of silver, lead, and tin; pyrite, chalcopyrite, and spalerite. Occurs also in serpentine.

Abundant at Freiberg; at Reichenstein in Silesia; at Schladming; Andreasberg; Joachimsthal ; at Tunaberg in Sweden; at Skutterud in Norway ; in Cornwall; in Devonshire at the Tamar mines.

In New Hampshide, in gneiss, at Franconia (danaite); also at Jackson and at Haverhill. In Maine, at Blue Hill, Corinna, etc. In Vermont, at Brookfield, Waterbury, and Stockbridge. In Mass., at Worcester and Sterling. In Conn., at Monroe, at Mine Hill, Roxbury. In Neroo Jersey, at Franklin. In N. York, massive, in Lewis, Essex Co., near Edenville, and elsewhere in Orange Co.; in Carmel ; in Kent, Putnam Co. In California, Nevada Co., Grass valley. In S. America, in Bolivia; also, niccoliferous var., between La Pas and Yungas in Bolivia (anal. by Krober).

LöLlimgite is $\mathrm{FeAs}_{2}$ (=Arsenic 72.8, iron 97.2 ), and Leucopyrite is $\mathrm{Fe}_{2} \mathrm{As}_{3}$ (=Arsenic $66 \cdot 8$, iron $33 \cdot 2$ ). They are both like arsenopyrite in form. Found, the former at Lölling; Schladming; Sätersberg, near Fossum, Norway; the latter at Reichenstein; Geyer (geyerite) near Hüttenberg, Carinthia.

Glavcodot $(\mathrm{Co}, \mathrm{Fe}) \mathrm{S}_{2}+(\mathrm{Co}, \mathrm{Fe}) \mathrm{AB}_{3}$, with $\mathrm{Co}: \mathrm{Fe}=2: 1=$ Sulphur $19 \cdot 4$, arsenic $45 \%$, cobalt $23 \cdot 8$, iron $11 \cdot 3=100$. Form like arsenopyrite. Huasco, Chili; Hakansbö, Swéden.
alloclasite $\mathbf{R}_{\mathbf{4}}(\Delta s, B i)_{7} \mathrm{~S}_{0}$, with $\mathrm{R}=\mathrm{Bi}, \mathrm{Co}, \mathrm{Ni}, \mathrm{Fe}, \mathrm{Zn}$. Orawicza, Hungary.


SYLVANITE. Graphic Tellurium. Schrifterz, Schrift-Tellux, Germ.
Monoclinic. $C=55^{\circ} 21 \frac{1}{2}^{\prime}, I \wedge I=94^{\circ} 26^{\prime}, O \wedge 1-\grave{\imath}=121^{\circ} 21^{\prime} ; c: b:$ $\hat{a}=1.7732: 0.889: 1$, Kokscharof. Cleavage $: i-i \quad$ distinct. Also massive; imperfectly columnar to granular.
$\mathrm{H} .=1 \cdot 5-2$. G. $=7 \cdot 99-8 \cdot 33$. Lustre metallic. Streak and color pure steelgray to silver-white, and sometimes nearly brass-yellow. Fracture uneven,
Comp., Var.- $(\mathrm{Ag}, \mathrm{Au}) \mathrm{Te}_{2}=($ if $\dot{\mathrm{Ag}}: \mathrm{Au}=1: 1)$ Tellurium $55 \cdot 8$, gold $28 \cdot 5$, silver $15 \cdot 7=100$ Antimony sometimes replaces part of the tellurium, and lead part of the other metals.

Pyr., etc.-In the open tube gives a white sublimate which near the assay is gray; when treated with the blowpipe flame the sublimate fuses to clear transparent drops. B.B. on charcoal fuses to a dark gray globule, covering the coal with a white coating, which treated in R.F. disappears, giving a bluish-green color to the flame; after long blowing a yellow malleable metallic globule is obtained. Most varieties give a faint coating of the oxides of lead and antimony on charcoal.

Obs.-Occurs at Offenbanya and Nagyag in Transylvania. In California, Calaveras Co., at the Melones and Stanislaus mines; Red Cloud mine, Colorado.

Named from Transylvania, the country in which it occurs, and in allusion to sylvanium, one of the names at first proposed for the metal tellurium. Called graphic because of a resemblance in the arrangement of the crystals to writing characters.

Schrauf has stated that, according to his measurements, sylvanite is orthorhombic.
Calaverite (Gentl.) has the composition $\mathrm{AuTe}_{4}=$ Tellurium $55 \cdot 5$, gold $44 \cdot 5=100$. Massive. Color bronze-yellow. Stanislaus mine, Cal. ; Red Cloud mine, Colorado.

NAGYAGITE.* Blättererz, Blättertellur, Germ.
Tetragonal. $O \wedge 1-i=127^{\circ} 37^{\prime} ; \dot{c}=1 \cdot 298 . \quad O \wedge 1=118^{\circ} 37^{\prime}$. Cleavage: basal. Also granularly massive, particles of various sizes; generally foliated.

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$\mathrm{H} .=1-1 \cdot 5 . \quad \mathrm{G} .=6 \cdot 55-7 \cdot 2$. Lustre metallic, splendent. Streak and color blackish lead-gray. Opaque. Sectile. Flexible in thin laminæ.


Comp.-Uncertain, perhaps $R(S, T e)_{2}$, with $\mathbf{R}=\mathrm{Pb}, \mathrm{Au}$ (Ramm.). Analysis, Schönlein, Te $30 \cdot 52$, S $8 \cdot 07$, $\mathrm{Pb} 50 \cdot 78$, $\mathrm{Au} 9 \cdot 11$, $\mathrm{Ag} 0 \cdot 53$, $\mathrm{Cu} 0 \cdot 99=100$.

Pyr., etc.-In the open tube gives, near the assay, a grayish sablimate of antimonate and telluıate, with perhaps some sulphate of lead; farther up the tube the sublimate consists of antimonous oxide, which volatilizes when treated with the flame, and tellurous oxide, which at a high temperature fuses into colorless drops. B.B. on charcoal forms two coatings : one white and volatile, consisting of a mixture of antimonite, tellurite, and sulphate of lead; and the other yellow, less volatile, of oxide of lead quite near the assay. If the mineral is treated for some time in O.F. a malleable globule of gold remains; this cupelled with a little assay lead assumes a pure gold color. Decomposed by nitro-hydrochloric acid.

Obs.-At Nagyag and Offenbanya in Transylvania, in foliated masses and crystalline plates.
Covellite (Kupferindig, Germ.).-Composition CuS=Sulphur $33 \cdot 5$, copper $66.5=100$. Hexagonal. Commonly massive. Color indigo-blue. Mansfeld, etc. ; Vesuvius, on lava; Chili.

Melonite (Genth.). -A nickel telluride, formula probably $\mathrm{Ni}_{2} \mathrm{Te}_{3}=$ tellurium 76.5 , nickel $23 \cdot \tilde{5}=100$. Hexagonal. Cleavage basal eminent. Color reddish-white. Streak dark-gray. Occurs mixed with other tellurium minerals at the Stanislaus mine, Cal.
3. TERNARY COMPOUNDS. Sulpharsenites, Sulphantimonites,
(a) Group I. Formula $\mathrm{R}(\mathrm{As}, \mathrm{Sb})_{2} \mathrm{~S}_{4}=\mathrm{RS}+(\mathrm{As}, \mathrm{Sb})_{2} \mathrm{~S}_{8}$.

MIARGYRITE.
Monoclinic. $C=48^{\circ} 14^{\prime} ; I \wedge I=106^{\circ} 31^{\prime}, O \wedge 1-\grave{\imath}=136^{\circ} 8^{\prime} ; c \cdot b: d$ $=1 \cdot 2883: 0.9991: 1$, Naumann. Crystals thick tabular, or stout, or short prismatic, pyramidal. Lateral planes deeply striated. Cleavage: $\frac{1}{2}-i, 1-i$ in inperfect.

[^32]H. $=2-2 \cdot 5$. G. $=5 \cdot 2-5 \cdot 4$. Lustre submetallic-adamantine. Color iron black. Streak dark cherry-red. Opaque, except in thin splinters, waich by transmitted light, are deep blood-red. Fracture subconchoidal.

Comp.-AgSbS 2 (or $\mathrm{Ag}_{2} \mathrm{~S}+\mathrm{Sb}_{2} \mathrm{~S}_{3}$ ) = Sulphur 21.8, antimony $41 \cdot 5$, silver $36 \cdot \%=100$.
Pyr., etc.-In the closed tube decrepitates, fuses easily, and gives a sublimate of antimony sulphide; in the open tube sulphurous and antimonous fumes, the latter as a white sublimate. B. B. on charcoal fuses quietly, with emission of sulphur and antimony fumes, to a gray bead, which after continued treatment in O.F. leaves a bright globule of silver. If the silver globule be treated with phosphorus salt in O.F., the green glass thus obtained shows traces of copper when fused with tin in R.F.

Decomposed by nitric acid, with separation of sulphur and antimonous oxide.
Obs.-At Braünsdorf, near Freiberg in Saxony; Felsobanya (kenngottite); Przibram in Bohemia; Clausthal (hypargyrite) ; Guadalajara in Spain ; at Parenos, and the mine Sta M. de Catorce, near Potosi; also at Molinares, Mexico.

## SARTORITE. SCLEROCLASE.

Orthorhombic. $I \wedge I=123^{\circ} 21^{\prime}, O \wedge 1-\bar{\imath}=131^{\circ} 3^{\prime} ; \dot{c}: \bar{b}: \breve{c}=1 \cdot 1483$ : $1.8553: 1$. Crystals slender. Cleavage:

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 $O$ quite distinct.
$\mathrm{H} .=3$. G. $=5 \cdot 393$. Lustre metallic. Color dark lead-gray. Streak reddishbrown. Opaque. Brittle.

Comp. $-\mathrm{PbAs}_{2} \mathrm{~S}_{4}\left(\mathrm{PbS}+\mathrm{As}_{2} \mathrm{~S}_{3}\right)=$ Sulphur 26.4 , arsenic $30 \cdot 9$, lead $42 \cdot 7=100$.

Pyr., etc.-Nearly the same as for dufrenoy. site (q. v.), but differing in strong decrepitation.

Obs.-From the Binnen valley with dufrenoysite and binnite. As the name Scleroclase is inapplicable, and the mineral was first announced by Sartorius v. Waltershausen, the species may be appropriately called Sartorite. It is the binnite of Heusser.

## $\Varangle$ zinkentite.

Orthorhombic. $I \wedge I=120^{\circ} 39^{\prime}$, Rose. Usual in twins, as hexagonal prisms, with a low hexagonal pyramid at summit. Lateral faces longitudinally striated. Sometimes columnar, fibrous, or massive. Cleavage not distinct.
H. $=3-3 \cdot 5$. G. $=5 \cdot 30-5 \cdot 35$. Lustre metallic. Color and streak steelgray. Opaque. Fracture slightly uneven.

Comp. $-\mathrm{PbSb}_{2} \mathrm{~S}_{4}$ (or $\mathrm{PbS}+\mathrm{Sb}_{2} \mathrm{~S}_{3}$ ) $=$ Sulphur $22 \cdot 1$, antimony $42 \cdot 2$, lead $35 \cdot 7=100$.
Pyr., etc.-Decrepitates and fuses very easily ; in the closed tube gives a faint sublimate of sulphur and antimonous sulphide; in the open tube sulphurous fumes and a white sublimate of oxide of antimony. B.B. on charcoal is almost entirely volatilized, giving a coating which on the outer edge is white, and near the assay dark-yellow; with soda in R.F. yields globnles of lead.
Soluble in hot hydrochloric acid with evolution of sulphuretted hydrogen and separation of lead chloride on cooling.

Resembles stibnite and bournonite, but may be distinguished by its superior lardness and specific gravity.
Obs.-Occurs at Wolfsberg in the Harz.
Chalcostibite (Kupferantimonglanz, Germ.).-Composition $\mathrm{CuSbS}_{2}$ (or $\mathrm{Cu}_{2} \mathrm{~S}+\mathrm{Sb}_{2} \mathrm{~S}_{5}$ ) =: Sulphur $25 \%$, antimony $48 \cdot 9$, copper $25 \cdot 4$. Color lead-gray to iron-gray. Wolfsberg in the Harz.
Emplectite (Kupferwismuthglanz, Germ.).-Composition $\mathrm{CuBiS}_{2}$ (or $\mathrm{Cu}_{2} \mathrm{~S}+\mathrm{Bi}_{2} \mathrm{~S}_{3}$ ) $=\mathrm{Sul}$. phur $19 \cdot 1$, bismuth $62 \cdot 0$, copper $18 \cdot 9=100$. Color grayish to tin-white. Schwarzenherg, Scxony; Copiapo, Chili.

Berthiebite.-Composition approximately $\mathrm{FeSb}_{2} \mathrm{~S}_{4}$ (or $\mathrm{FeS}+\mathrm{Sb}_{2} \mathrm{~S}_{3}$ ) $=$ Sulphur $30^{\circ} 0$, antimony $57 \cdot 0$, iron $13 \cdot 0=100$. Color dark steel-gray. Auvergne; Bräunsdorf, Saxony; Cornwall, etc. ; San Antonio, Cal.

## (b) Sub-Group. Formula $\mathrm{R}_{3}\left(\mathrm{As}, \mathrm{Sb}, \mathrm{Bi}_{4}{ }_{4} \mathrm{~S}_{9}=3 \mathrm{RS}+2(\mathrm{As}, \mathrm{Sb}, \mathrm{Bi})_{2} \mathrm{~S}_{3}\right.$.

Plagionite.-Composition (Rose) $\mathrm{Pb}_{4} \mathrm{Sb}_{6} \mathrm{~S}_{13}$ (or $4 \mathrm{PbS}+3 \mathrm{Sb}_{2} \mathrm{~S}_{3}$ ) = Sulphur $21 \cdot 1$, antimony $37 \cdot 0$, lead 41.9 . Monoclinic. G. $=5 \cdot 4$. Found at Wolfsberg in the Harz.

Jordanite (v. Rath).-Composition $\mathrm{Pb}_{3} \mathrm{As}_{4} \mathrm{~S}_{9}$ (or $3 \mathrm{PbS}+2 \mathrm{As}_{2} \mathrm{~S}_{3}$ ) $=$ Sulphur $23 \cdot 8$, arsenic 24.8 , lead 51.4 . Orthorhombic. Resembles sartorite, but distinguished by its black streak, its six-sided twins, and by not decrepitating B.B. Binnenthal, Switzerland.

Binnite. -Composition probably $\mathrm{Cu}_{6} \mathrm{As}_{4} \mathrm{~S}_{9}$ (or $3 \mathrm{Cu}_{2} \mathrm{~S}+2 \mathrm{As}_{2} \mathrm{~S}_{3}$ ) = Sulphur $29 \cdot 7$, arsenic $31 \cdot 0$, copper $39 \% 3=100$. Isometric. Streak cherry-red. Binnenthal in dolomite (dufrenoysite of v. Waltershausen).

Klaprotiolite (Petersen). - Composition $\mathrm{Cu}_{6} \mathrm{Bi}_{4} \mathrm{Sb}_{9}$ (or $3 \mathrm{Cu}_{2} \mathrm{~S}+2 \mathrm{Bi}_{2} \mathrm{~S}_{3}$ ). Orthorhombic. Cleavage $i \cdot \boldsymbol{\imath}$ distinct. Color steel-gray. G. $=4 \cdot 6$. Wittichen, Baden.

Schirmerite ( Genth).-Composition $\mathrm{R}_{3} \mathrm{Bi}_{4} \mathrm{~S}_{9}$ (or $3 \mathrm{RS}+2 \mathrm{Bi}_{2} \mathrm{~S}_{3}$ ), with $\mathrm{R}=\mathrm{Ag}_{2}: \mathrm{Pb}=\mathbf{2}: 1$. This requires sulphur $16^{\circ} 4$. bismuth $47 \cdot 3$, silver $24 \cdot 5$, lead $11 \cdot 8=100$. Massive, disseminated in quartz. Color lead-gray. Red Clond mine, Colorado.
(c) Group II. Formula $\mathrm{R}_{2}(\mathrm{Sb}, \mathrm{As})_{2} \mathrm{~S}_{5}=2 \mathrm{RS}+(\mathrm{Sb}, \mathrm{As})_{2} \mathrm{~S}_{3}$.

JAMESONITE. Federerz, Germ.
Orthorhombic. $I \wedge I=101^{\circ} 20^{\prime}$ and $78^{\circ} 40^{\prime}$. Cleavage basal, highly perfect; $I$ and $i-\imath$ less perfect. Usually in acicular crystals. Also fibrous massive, parallel or divergent; also in capillary forms; also amorphous massive.
H. $=2-3$. G. $=5 \cdot 5-5 \cdot 8$. Color steel-gray to dark lead-gray. Streak gray.

Comp. $-\mathrm{Pb}_{2} \mathrm{Sb}_{2} \mathrm{~S}_{5}$ (or $2 \mathrm{PbS}+\mathrm{Sb}_{2} \mathrm{~S}_{3}$ ) ; more strictly $2 \mathrm{PbS}=2($ or $\mathrm{Pb}, \mathrm{Fe}$ ) S . If $\mathrm{Fe}: \mathrm{Pb}=1$ : 4, Sulphur $21 \cdot 1$, antimony $32 \cdot 2$, lead $43 \%$, iron $3 \cdot 0=100$. Small quantities of zinc, bismuth, silver, and copper are also sometimes present.
Pyr.-Same as for zinkenite.
Diff.-Distinguished from other related species by its perfect basal cleavage.
Obs.-Jnmesonite occurs principally in Cornwall, in Siberia, Hungary, at Valentia, d'Alcantara in Spain, and Brazil.
The feather ore occurs at Wölfsberg in the Eastern Harz; also at Andreasberg and Clausthal ; at Freiberg and Schemnitz ; at Pfaffenberg and Meiseberg ; in Tuscany, near Bottino ; at Chonta in Peru.

## DUFRENOYSITE.

Orthorhombic. $I \wedge I=93^{\circ} 39^{\prime}, O \wedge 1-\bar{\imath}=121^{\circ} 30^{\prime}, c \in: \bar{b}: \breve{a}=1 \cdot 6318$ : $1 \cdot 0658: 1$. Usual in thick rectangular tables. Cleavage: $O$ perfect. Also massive.
$\mathrm{H} .=3$. G$\cdot=5 \cdot$.549-5.569. Lustre metallic. Color blackish lead-gray. Streak reddish-brown. Opaque. .Brittle.

[^33] the open tube a smell of sulphur only, with a sublimate of sulphur in upper part of tube. and
of arsenous oxide below. On charcoa: decrepitates, melte, yields fumes of arsenic and \& globule of lead, which on cupellation yields silver.

Obs.-From the Binnenthal in the Alps, in crystalline dolomite, along with sartorite, jordanite, binnite, etc.

Damour, who first studied the arsenio-sulphides of the Binnenthal, analyzed the massive ore and named it dufrenuysite. He inferred that the crystallization was isometric from somo associated crystals, and so published it. This led von Waltershausen and Heusser to call the isomctric mineral dufrenoysite, and the latter to na ne the orthorhombic species binnite. Von Waltershausen, after studying the prismatic mineral, made out of the species arsenomelan and sclernolase, yet partly on hypothetical grounds. Recently it has been found that three orthorhombic minerals exist at the locality, as announced by vom Rath, who identifies one, by specific gravity and composition, with Damour's dufrenoysite; another he makes scleroclase of von Waltershausen (sartorite, p. 250) ; and the other he names jordanite (p.251). The isometric mineral was called binnite by DesCloizeaux.

Freiestebenite. Schilfglaserz, Germ.
Monoclinic. $C=87^{\circ} 46^{\prime}, I \wedge I=119^{\circ} 12^{\prime}, O \wedge 1-\grave{\imath}=137^{\circ} 10^{\prime}$ (B. \& M.); $\dot{c}: \bar{b}: \grave{a}=1.5802: 1.7032: 1 . \quad 0 \wedge 1-i=123^{\circ} 55^{\prime}$.
 Prisms longitudinally striated. Cleavage: $I$ perfect.
$\mathrm{H} .=2-2 \cdot 5 . \quad$ G. $=6-6 \cdot 4$. Lustre metallic. Color and streak light steel-gray, inclining to silver-white, also blackish lead-gray. Yields easily to the knife, and is rather brittle. Fracture subconchoidal-uneren.

Comp. $-\mathrm{Pb}_{2} \mathrm{Ag}_{3} \mathrm{Sb}_{3} \mathrm{~S}_{\text {8, }}$ Ramm. (or $7 \mathrm{RS}+3 \mathrm{Sb}_{2} \mathrm{~S}_{3}$, with $7 \mathrm{RSS}=4 \mathrm{PbS}$ $+3 \mathrm{Ag}_{2} \mathrm{~S}$ ) $=$ Sulphur $18 \cdot 8$, antimony $26 \cdot 9$, lead $30 \cdot 5$, silver $23 \cdot 8=100$.

Pyr.-In the open tube gives sulphurous and antimonial fumes, the latter condensing as a white sublimate. B.B. on charcoal fuses easily, giving a coating on the outer edge white, from antimonous oxide, and near the assay yellow, from oxide of lead; continued blowing leaves a globule of silver.
Obs.-Occurs at Freiberg in Saxony and Kapnik in Transylvania; at Rátieborzitz; at Przibram; at Felsöbanya; at Hiendelencina in Spain.
According to v. Zepharovich, the mineral from Przibram and Bräunsdorf, and part of that from Freiberg, while identical in composition with freieslebenite, has an orthn'hombic form. It is called by him diapiorite.

Brongniardite.--Composition $\mathrm{Ag}_{2} \mathrm{PbSb}_{2} \mathrm{~S}_{5}$ (or $\mathrm{PbS}+\mathrm{Ag}_{2} \mathrm{~S}+\mathrm{Sb}_{2} \mathrm{~S}_{3}$ ) $=$ Sulphur $19 \cdot 4$, antimony $29 \cdot 5$, silver $26 \cdot 1$, lead $25 \cdot 0=100$. Isometric; in octahedrons, also massive. Color gray-ish-black. Mexico.

Cosalite (Genth). -Composition $\mathrm{Pb}_{2} \mathrm{Bi}_{2} \mathrm{~S}_{5}$ (or $2 \mathrm{PbS}+\mathrm{Bi}_{2} \mathrm{~S}_{3}$ ) = Sulphur $16 \cdot 1$, bismuth $42 \cdot 2$, lead $41 \cdot 7=100$. Color lead-gray. Soft and brittle. Cosala, Sinaloa, Mexico. Identical (Frenzel) with Hermann's retzbanyite.

Pyrostilpnite (Feuerblende, Germ.).-In delicate crystals; color hyacinth-red. Contains 62.3 p. c. silver, also sulphur and antimony. Freiberg ; Andreasberg; Przibram.
Rittingerite.-In minute tabular crystals. Color black Streak orange-yellow. Contains sulphur, antimony, and silver. Joachimsthal.
(d) Group III. Formula $\mathrm{R}_{3}(\mathrm{As}, \mathrm{Sb})_{i 2} \mathrm{~S}_{6}=3 \mathrm{RS}+(\mathrm{As}, \mathrm{Sb})_{2} \mathrm{~S}_{3}$.

PYRARGYRITE. Ruby Silver. Dark Red Silver Ore. Dunkles Rothgültigerz, Germ.
Rhombohedral. Opposite extremities of crystals often unlike. $R \wedge F$ $=108^{\circ} 42^{\prime}\left(\mathrm{B} . \& \mathrm{M}\right.$ ) $; O \wedge R=137^{\circ} 42^{\prime} ; \dot{c}=0.788$. $O \wedge 1^{3}=112^{\circ} 33^{\prime}$, $0 \wedge 1^{7}=10 \dot{y}^{\circ} 14^{\prime}, R \wedge \frac{1}{2}=144^{\circ} 21^{\prime}$. Cleavage: $R$ rather imperfect

Twins: composition-face $-\frac{1}{2} ; O$ or basal plane, as in f. 290, p. 95 ; als $R$ and $I$. Also massive, structure granular, sonetimes impalpable.
H. $=2-2 \cdot 5 . \quad$ G. $=5 \cdot 7-5^{\circ} 9 . \quad$ Lustre metallic-adanantine. Color black, sometimes approaching cochineal-red. Streak cochineal-red. Translucentopaque. Fracture coonchoidal.

Ccmp. $-\mathrm{Ag}_{3} \mathrm{SbS}_{3}$ (or $3 \mathrm{Ag}_{2} \mathrm{~S}+\mathrm{Sb}_{2} \mathrm{~S}_{3}$ ) $=$ Sulphar $17 \cdot 7$, antimony $22 \cdot 5$, silver $59 \cdot 8=100$.

Pyr. eic.-In the closed tube fuses and gives


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 a reduish sublimate of antimonous sulphide; in the open tube sulphurous fumes and a white sublimate of antimonous oxide. B.B. or charcoal fuses with spirting to a globule, gives off antimonous sulphide, coats the coal white, and the assay is converted into silver sulphide, which, treated in O.F., or with soda in P.F., gives a globule of fine silver. In case arsenic is present it may be detected by fusing the pulverized mineral with soda on charcoal in R.F.

Decomposed by nitric acid with separation of sulphur and antimonous oxide.
Obs.-Occurs principally with calcite, native arsenic and galenite, at Andreasberg ; also in Saxony, Hungary, Norway, at Gaudalcanal in Spain, and in Cornwall. In Mexico abundant. In Chili ; in Nevada, at Washoe in Daney Mine; abundant about Austin, Reese river ; at Poor Man lode, Idaho.

PROUSTITE. Light Red Silver Ore. Lichtes Rothgültigerz, Germ.
Rhombohedral. $R \wedge R=107^{\circ} 48^{\prime}, O \wedge R=137^{\circ} 9^{\prime} ; \dot{c}=0.78506$. Also granular massive.
H. $=2-2 \cdot 5 . \quad$ G. $=5 \cdot 422-5 \cdot 56$. Lustre adamantine. Color cochineal-red. Streak corhineal-red, sometimes inclined to aurora-red. Subtransparentsubtranslucent. Fracture conchoidal-uneven.

Comp. $-\mathrm{Ag}_{3} \mathrm{AsS}_{3}$ (or $3 \mathrm{Ag}_{2} \mathrm{~S}+\mathrm{As}_{2} \mathrm{~S}_{3}$ ) $=$ Sulphur $19 \cdot 4$, arsenic $15 \cdot 1$, silver $65 \cdot 5=100$.
Pyr., etc.-In the closed tube fuses easily, and gives a faint sublimate of arsenous sulphide ; in the open tube sulphurous fumes and a white crystalline sublimate of arsenous oxide. B.B. on charcoal fuses and emits odors of sulphur and arsenic ; by prolonged heating in O.F., or with soda in R.F., gives a globule of pure silver. Some varieties contain antimony.

Decomposed by nitric acid, with separation of sulphur and arsenous oxide.
Obs.-Occurs at Freiberg and elsewhere in Saxony; at Joachimsthal ; Wolfach in Baden; Chalanches in Dauphiné; Guadalcanal in Spain ; in Mexico: Peru; Chili, at Chanarcillo, in magnificent crystals. In Nevada, in the Daney mine, and in Comstock lode, but rare; in veins about Austin, Lander Co. ; in microscopic crystals in Cabarrus Co., N. C., at the McMakin mine ; in Idaho, at the Poor Man lode.

## BOURNONITE. Rädelerz, Germ.(=Wheel Ore),

Orthorhombic. $I \wedge I=93^{\circ} 40^{\prime}, O \wedge 1-\bar{\imath}=136^{\circ} 17^{\prime}$ (Miller) ; i $\bar{b}: \check{a}=$ $0.95618: 1.0662: 1$. $O \wedge 1-\overline{2}=133^{\circ} 26^{\prime}, O \wedge 1=127^{\circ} 20^{\prime}, 0 \wedge 1-\tau=135^{\circ}$ $6^{\prime}$. Cleavage : $i-\varkappa$ imperfect ; $i-\bar{\imath}$ and $O$ less distinct. Twins: twimning. plane face $\overline{0}$; crystals often cruciform (f. 453), crossing at angles of $93^{\circ}$ $40^{\prime}$ and $86^{\circ} 20^{\prime}$; hence, also, cog-wheel shaped. Also massive; granular compact.
$\mathrm{H} .=2 \cdot 0-3 . \quad \mathrm{G} .=5 \cdot 7-5 \cdot 9 . \quad$ Lustre metallic. Color and streak steel-gray, inclining to blackish lead-gray or iron-black. Opaque. Fracture conchoidal or uneven. Brittle.

 antimony $25 \cdot 0$, lead $42 \cdot 4$, copper $13 \cdot 0=100$.

Pyr., etc.-In the closed tube decrepitates, and gives a dark-red sublimate. In the open tube gives sulphurous oxide, and a white sublimate of antimonous oxide. B.B. on charcoal fuses easily, and at first coats the coal white, from antimonous oxide; continued blowing gives a yellow coating of lead oxide; the residue, treated with soda in R.F., gives a globule of copper.

Decomposed by nitric acid, affording a blue solution, and leaving a residue of sulphur, and a white powder containing antim iny and lead.

Obs.-Occurs in the Harz; at Kapnik in Transylvania; at Servoz in Piedmont: Bräunsdorf and Gersdorf in Saxony, Olsa in Corinthia, etc.; in Cornwall; in Mexico; at Huascoalto in Chili; at Machacamarca in Bolivia; in Peru.

Stylotypite.-An iron-silver-copper bournonite; Copiapo, Chili.

## BOULANGERITE.

In plumose masses, exhibiting in the fracture a crystalline structure; also granular and compact.
$\mathrm{H} .=2.5-3 . \quad \mathrm{G} .=5.75-6.0$. Lustre metallic. Color bluish lead-gray; often covered with yellow spots from oxidation.

Comp. $-\mathrm{Pb}_{3} \mathrm{Sb}_{2} \mathrm{~S}_{6}$ (or $3 \mathrm{PbS}+\mathrm{Sb}_{2} \mathrm{~S}_{3}$ ) $=$ Sulphur $18 \cdot 2$, antimony $23 \cdot 1$, lead $58 \cdot 7=100$.
Pyr.-Same as for zinkenite.
Obs.-Quite abundant at Molières, department of Gard, in France; also found at Nasafjeld in Lapland ; at Nertschinsk: Ober-Lahr in Sayn-Altenkirchen; Wolfsberg in the Harz; near Bottino in Tuscany.
Epiboulangerite.-Probably a decomposition product of boulangerite (Websky) ; it contains more sulphur and less antimony. Altenberg, Silesia.

Wittichenite.-Composition $\mathrm{Cu}_{3} \mathrm{BiS}_{3}$ (or $3 \mathrm{Cu}_{2} \mathrm{~S}+\mathrm{Bi}_{2} \mathrm{~S}_{3}$ )= Sulphur $19 \cdot 4$, bismuth 42.1, oopper $38 \cdot 5=100$. Coior steel-gray. Wittichen, Baden.
Kobelinte. - $\mathrm{Pb}_{3}$ BiSbS $_{6}$ (or $3 \mathrm{PbS}+\left(\mathrm{Bi} . \mathrm{Sb}_{2} \mathrm{~S}_{3}\right.$ ) Ramm. $=$ Sulphur 16.8 , antimony 107 , bismuth $18 \cdot 2$, lead $54 \cdot 3=100$. Color lead-gray to steel-gray. Hvena, Sweden.

Aikinite (Nadulerz, Germ.).- $\mathrm{CuPbBiS}_{3}$ (or $\mathrm{Cu}_{2} \mathrm{~S}+2 \mathrm{PbS}+\mathrm{Bi}_{2} \mathrm{~S}_{3}$ ) $=$ Sulphur 167, bismuth $36 \cdot 2$, lead $36 \cdot 0$, copper $11 \cdot 1=100$. In acicular crystals, also massive. Color blackish leaid gray. Beresof, Urals ; Gold Hill, North Carolina.

## (e) Group IV. Formula $\mathrm{R}_{4}\left(\mathrm{As}, \mathrm{Sb}, \mathrm{Bi}_{2}\right)_{2} \mathrm{~S}_{7}=4 \mathrm{RS}+(\mathrm{As}, \mathrm{Sb}, \mathrm{Bi})_{2} \mathrm{~S}_{3}$.

TETRAHEDRITE.* Gray Copper Ore. Fahlerz; Antimon- and Quecksilberfahlerz, Germ
Isometric ; tetrahedral. Twins: twinning-plane octahedral, producing, when the composition is repeated, the form in f. 456. Also massive; granular, coarse, or fine ; compact or crypto-crystalline.

$\mathrm{H} .=3-4 \cdot 5$. G. $=4 \cdot 5-5 \cdot 56$. Lustre metallic. Color between light flintgray and iron-black. Streak generally same as the color ; sometimes inclined to brown and cherry-red. Opaque; sometimes subtranslucent in very thin splinters, trausmitted color cherry-red. Fracture subconchoidal - meven. Rather brittle.

Comp., Var. $-\mathrm{Cu}_{8} \mathrm{Sb}_{2} \mathrm{~S}_{7}$ ( or $4 \mathrm{Cu}_{2} \mathrm{~S}+\mathrm{Sb}_{2} \mathrm{~S}_{3}$ ), with part of the copper ( $\mathrm{Cu}_{2}$ ) often replaced by iron ( $\left.\mathrm{F}^{\prime} \mathrm{e}\right)$, zinc $(\mathrm{Zn})$, silver $\left(\mathrm{Ag}_{2}\right)$, or quicksilver ( Hg ), and rarely cobalt (Co), and part of the antimony by arsenic, and rarely bismuth. Ratio $\mathrm{Ag}_{2}+\mathrm{Cu}_{2}: \mathrm{Zn}+\mathrm{Fe}$ generally $=2: 1$. There are thus:
A. An antimonial series; B. An arsenio-antimonial series; C. A bismuthic arsenio-antimonial; besides an arsenical, in which arsenic replaces all the antimony, and which is made into a distinct species named tennantite.

Var. 1. Ordinary. Containing little or no silver. Color stecl-gray to dark-gray.
2. Argentiferous; Freibergite. Light steel-gray, sometimes iron-black.
3. Mercuriferous; Schwatzite. Color gray to iron-black.

The following analyses will serve as examples of these varieties :


Pyr., etc.-Differ in the different varieties. In the closed tube all fuse and give a darkred sublimate of antimonous sulphide; when containing mercury, a faint dark-gray sublimate appears at a low red heat; and if much arsenic, a sublimate of arsenous sulphide first forms. In the open tube fuses, gives sulphurous fumes and a white sublimate of antimony; if arsenic is present a crystalline volatile sublimate condenses with the antimony; if the ore contains mercury it condenses in the tube in minute metallic globules. B. B. on charcoal fuses. gives a coating of antimonous oxide and sometimes arsenous acid, zinc oxide, and lead oxide ; the arsenic may be detected by the odor when the coating is treated in R.F.; the zinc oxide assumes a green color when heated with cobalt solution. The roasted minerai gives with the fluxes reactions for iron and copper ; with soda yields a globule of metallio copper. To determine the presence of a trace of arsenic by the odor, it is hest to fuse the mineral on charcoal with soda. The presence of mercury is best ascertained by fusing the
pulverized ore in a closed tube with about three times its weight of dry soda, the metal subliming and condensing in minute globules. The silver is determined by cupellation.

Decomposed by nitric acid, with separation of sulphur, and antimonous and arsenous oxides.
Obs.-The Cornish mines, near St. Aust. ; at Andreasberg and Clausthal in the Harz; Kremnitz in Hungary; Freiberg in Saxony ; Przibram in Bohemia; Kahl in Spessart; Kapnik in Transylvania; Dillenburg in Nassaiu ; and other localities. The ore containing mercury occurs in Schmölnitz, Hungary ; at Schwatz in the Tyrol ; and in the valleys of Angina and Costello in Tuscany.
Found in Mexico, at Durango, etc.; at various mines in Chili; in Bolivir ; at the Kellogg mines. Arkansas ; at Newburyport, Mass. In California in Mariposa Co. ; in Shasta Co. In Nevada, abundant at the Sheba and De Soto mines, Humboldt Co. ; near Austin in Lander Co.; in Arizona at the Heintzelman mine, containing $1 \frac{1}{2}$ p. c. of silver; at the Sana Rita mine.
lionite (Brauns).-A bismuth tetrahedrite from Cremenz, Einfischthal, Switzerland.
Malinowskite.-A tetrahedrite containing 9-13 p. c. lead, and 10-13 p. c. silver. District of Rocuay, Peru. (5th Append. Min. Chili.)

## tennantite.* Graukupfererz, Germ.

Isometric; holohedral, Phillips. Cleavage: dodecahedral imperfect. Twins as in tetrahedrite. Massive forms unknown.
$\mathrm{H} .=3 \cdot 5-4$. G. $=4 \cdot 37-4 \cdot 53$. Lustre metallic. Color blackish lead-gray to iron-black. Streak dark reddish-gray. Fracture uneven.

Comp.- $\mathrm{Cu}_{8} \mathrm{As}_{2} \mathrm{~S}_{7}$ (or $4 \mathrm{Cu}_{2} \mathrm{~S}+\mathrm{As}_{2} \mathrm{~S}_{3}$ ), with $\mathrm{Cu}_{2}$ replaced in part by $\mathrm{Fe}, \mathrm{Ag}_{2}$, etc., as in tetrahedrite, with which it agrees in crystalline form.

Pyr.-In the closed tube gives a sublimate of arsenous sulphide. In the open tube gives sulphurous fumes, and a sublimate of arsenous oxide. B.B. on charcoal fuses with intumescence and emission of arsenic and sulphur fumes to a dark-gray magnetic globule. The roasted mineral gives reactions for copper and iron with the fluxes; with soda on charcoal gives metallic copper with iron.

Obs.-Found in the Cornish mines. Also at Skutterud in Norway, and in Algeria.
Julianite (Websky) is near tennantite. G. $=5 \cdot 12$. Rudelstadt, Silesia.
MENEGIIINITE has the composition $\mathrm{Pb}_{4} \mathrm{Sb}_{2} \mathrm{~S}_{7}\left(4 \mathrm{PbS}+\mathrm{Sb}_{2} \mathrm{~S}_{3}\right)=$ Sulphur $17 \cdot 3$, antimony $16 \cdot 8$, lead $63 \cdot 9=100$. Resembles boulangerite. Bottino, Tuscany; Schwarzenberg, Saxony.

## $(f)$ Group V. Formula $\mathrm{R}_{5}\left(\mathrm{As}, \mathrm{Sb}_{2}\right)_{2} \mathrm{~S}_{8}=5 \mathrm{RS}+(\mathrm{As}, \mathrm{Sb})_{2} \mathrm{~S}_{3}$.

STEPHANITE. Sprödglaserz, Gcrm.
Orthorhombic. $I \wedge I=115^{\circ} 39^{\prime}, O \wedge 1-\bar{\imath}=132^{\circ} 32 \frac{1}{2}^{\prime} ; \dot{c}: \bar{b}: \breve{a}=1 \cdot 089^{\prime}$
457 $: 1.5844: 1$. $\quad 0 \wedge 1=127^{\circ} 51^{\prime}, 0 \wedge 1-乞=145^{\circ} 34$ : Cleavage : $2-\check{\imath}$ and $i-\varkappa$ imperfect. Twins: twinning-plane $I$;
 forms like those of aragonite frequent. Also inassive, compact, and disseminated.
H. $=2-2 \cdot 5 . \quad \mathrm{G} .=6 \cdot 269$, Przibram. Lustre metallic. Color and streak iron-black. Fracture uneven.

Comp. $-\mathrm{Ag}_{5} \mathrm{SbS}_{4}$ (or $5 \mathrm{Ag}_{2} \mathrm{~S}+\mathrm{Sb}_{2} \mathrm{~S}_{3}$ )=Sulphur $16 \cdot 2$, antimony $15 \cdot 3$, silver $68.5=100$.

Pyr. - In the closed tube decrepitates, fuses, and after long heating gives a faint sublimate of antimonous sulphide. In the open tube fuses, giving off antimonial fumes and sulphurous oxide. B. B. on charcoal fuses with projection of small particles, coats the coal with antimonous oxide, which after long blowing is colored red from oxidized silver, and a globule of metallic silver is obtained.
Soluble in dilute heated nitric acid, sulphur and oxide of antimony being deposited.

Cbs-At Freiberg and elsewhere in Saxony; at Przibram in Bohemia; in IIungary; at Andreasberg; at Zacatecas in Mexico; and in Peru. In Nevada, an abundant silver ore in the Comstock lode; at Ophir and Mexican mines in fine crystals; in the Reese river and Humboldt and other regions. In Idaho, at the silver mines.

Geocronite.-Composition $\mathrm{Pb}_{5} \mathrm{Sb}_{4} \mathrm{~S}_{6}\left(\right.$ or $\left.5 \mathrm{PbS}+\mathrm{Sb}_{2} \mathrm{~S}_{3}\right)=$ Sulphur 16.7 , antimony 15.9 , lead $67 \cdot 4=100$ (also contains a little arsenic). Color light lead-gray. Sala, Sweden; Merido, Soam; Val di Castello, Tuscany.

## POLYBASITE.

Orthorhombic, DesCl. I $I \wedge$ nearly $120^{\circ}, O \wedge 1=121^{\circ} 30^{\prime}$. Crystals usually short tabular prisms, with the bases triangularly striated parallel to alternate edges. Cleavage : basal imperfect. Also massive and disseminated.
H. $=2-3$. G. $=6.214$. Lustre metallic. Color iron-black; in thin crystals cherry-red by transmitted light. Streak iron-black. Opaque except when quite thin. Fracture uneven.

Comp.- $\mathrm{Ag}_{9} \mathrm{SbS}_{6}$ (or $9 \mathrm{Ag}_{2} \mathrm{~S}+\mathrm{Sb}_{2} \mathrm{~S}_{3}$ ), if containing silver without copper or arsenic, Sulphor $14 \cdot 8$, antimony $9 \cdot 7$, silver $955=100$. But with $\mathrm{Ag}_{2}$ replaced in part by $\mathrm{Cu}_{2}$ (ratio $\mathrm{Ag}: \mathrm{Cu}=$ $1: 4$ to $1: 11$ ), and Sb replaced by As (ratio $1: 1$, etc.).

Pyr., etc.-In the open tube fuses, gives sulphurous and antimonial fumes, the latter forming a white sublimate, sometimes mixed with crystalline arsenous oxide. B.B. fuses with spirting to a globule, gives off sulphur (sometimes arsenic), and coats the coal with antimonous oxide; with long-continued blowing some varieties give a faint yellowish-white coating of zinc oxide, and a metallic globule, which with salt of phosphorus reacts for copper, and cupelled with lead gives pure silver.

Decomposed by nitric acid.
Obs.-Occurs in Mexico; at Tres Puntos, Chili ; at Freiberg and Przibram. In Nevada, at the Reese mines; in Idaho, at the silver mines of the Owhyhee district.

Polyargyrite.-Isometric. Cleavage cubic. Malleable. Comp. $12 \mathrm{Ag}_{2} \mathrm{~S}+\mathrm{Sb}_{2} \mathrm{~S}_{3}$. Wolfach, Baden.

## ENARGITE.

Orthorhombic. $I \wedge I=97^{\circ} 53^{\prime}, O \wedge 1-\bar{\imath}=136^{\circ} 37^{\prime}$ (Dauber) $; \dot{c}: \ddot{b}: \breve{a}=$ $0.94510: 1.1480: 1$. $O \wedge 1-\check{\imath}=140^{\circ} 20^{\prime}, O \wedge 1=128^{\circ} 35^{\prime}$. Cleavage : $I$ perfect; $i-\bar{\imath}, i-\imath$ distinct; $O$ indistinct. Also massive, granular or columnar.
H. $=3$. G. $=4 \cdot 43-4 \cdot 45 ; 4 \cdot 362$, Kenngott. Lustre metallic. Color grayish to iron-black; streak grayish-black, powder having a metallic lustre. Brittle. Fracture uneven.

Comp.- $\mathrm{Cu}_{3} \mathrm{AsS}_{4}=$ sulphur $32 \cdot 5$, arsenic $19 \cdot 1$, copper $48 \cdot 4=100$, usually containing also a little antimony, and zinc, and sometimes silver.

Pyr.-In the closer ${ }^{7}$ tube decrepitates, and gives a sublimate of sulphur; at a higher temperature fuses, and gives a sublimate of arsenous sulphide. In the open tube, heated gently, the powdered mineral gives nff sulphurous and arsenous oxides, the latter condensing to a sublimate containing some antimonous oxide. B.B. on charcoal fuses, and gives a faint coating of arsenous oxide, antimonous oxide, and zinc oxide; the roasted mineral with the flaxes gives a globale of metallic copper.

Soluble in nitro-hydrochloric acid.

Obs.-From Morococha, Cordilleras of Peru; Famatina M! s., Argentine Republic ; from Chili; mines of Santa Anna, N. Granada; at Cosihuirachi in Mexico ; Brewster's gold mine, Chesterfield district, S. Carolina; in Colorado ; at Willis's Gulch, near Black Hawk; southern Utah; Morning Star mine, Cal.

Famatinite (Stelzner).-An antimonial enargite. Massive. Color reddish gray. Famatina Mts., Argentine Republic ; Cerro de Pasca, Peru.

Luzonite.-Similar to enargite in composition, but unlike in form, according to Weisbach. Mancayan Island, Luzon.
Clarite (Sandberger).-Also similar to enargite in composition, but in form monoclinic, and having a perfect cleavage parallel to the clinopinacoid. Schapbach, Black Forest.

Epigenite.-Composition S $32 \cdot 24$, As $12 \cdot 78, \mathrm{Cu} 4068, \mathrm{Fe} 14 \cdot 20=100$. Orthorhombia Color steel-gray. Neuglück mine, Wittichen.

# III. COMPOUNDS OF CHLORINE, BROMINE, IODINE 

## 1. ANHYDROUS CHLORIDES, ETC.

HALITE. COMMON SALT. Kochsalz, Steinsalz, Germ.
Isometric. Usually in cubes; rarely in octahedrons; faces of crystals sometimes cavernous, as in f. 458. Cleavage : cubic, perfect. Massive and granular, rarely columnar.
II. $=2 \cdot 5$. G. $=2 \cdot 1-2 \cdot 257$. Lustre vitreous. Streak white. Color white, also sometimes yellowish, reddish, bluish, purplish; often colorless. Transparent -translucent. Fracture conchoidal. Rather brittle. Soluble; taste purely saline.

Comp. $-\mathrm{NaCl}=$ Chlorine $60 \cdot 7$, sodium $39 \cdot 3=100$. Commonly niixed with some calcium sulphate, calcium chloride, and magnesium chloride. and sometimes magnesium sulphate, which render
 it liable to deliquesce.

Pyr. ets.-In the closed tube fuses, often with decrepitation; when fused on the platinum loop colors the flame deep yellow.

Diff.-Distinguished by its taste, solubility, and perfect cubic cleavage.
Obs.-Common salt occurs in extensive but irregular beds in rocks of various ages, associated with gypsum, polyhalite, calcite, clay, and sandstone; also in solution, and forming salt springs.

The principal mines of Europe are at Wieliczka, in Poland; at Hall, in the Tyrol ; Stassfurt, in Prussian Saxony; and along the range through Reichenthal in Bavaria, Hallein in Salzburg. Hallstadt, Ischl, and Ebensee, in upper Austria, and Aussee in Styria; in Transylvania; Wallachia, Galicia, and upper Silesia; Vic and Dieuze in France; Valley of Cardona and elsewhere in Spain, forming hills 300 to 400 feet high; Bex in Switzerland ; and Northwich in Cheshire, England. It also occurs near Lake Oroomiah, the Caspian Lake., etc. In Algeria; in Abyssinia; in India in the province of Lahore, and in the valley of Cashmere; in China and Asiatic Russia ; in South America, in Peru, and at Zipaquera and Nemocon.

In the United States, salt has been found forming beds with gypsum, in Virginia, Washington Co.; in the Salmon River Mts. of Oregon; in Louisiana. Brine springs are very numerous in the Middle and Western States. These springs are worked at Salina and Syracase, N. Y. ; in the Kanawha Valley, Va. ; Muskingum, Ohio; Michigan, at Saginaw and elsewhere ; and in Kentucky. Vast lakes of salt water exist in many parts of the world. Lake Timpanogos in the Rocky Mountains, 4,200 feet above the level of the sea, now called the Great Salt Lake, is 2,000 square milcs in area. L. Gale found in this water 20.196 per cent. of sodium chloride in 1852 ; but the greater rainfall of the last few years has diminished the proportion of saline matter. The Dead and Caspian Seas are salt, and the water of the former contain 20 to 26 parts of solid matter in 100 parts.

Huantajayite.-Composition $20 \mathrm{NaCl}+\mathrm{AgCl}$. Gccurs in white cubes in the mine of San Simon, Cerro de Huantajaya, Peru.

## SYLVITE.

Isometric. Cleavage cubic. Also compact.
$\mathrm{H} .=2$. G. $=1 \cdot 9-2$. White or colorless. Vitieous. Soluble; taste like that of common salt.

Comp. $-\mathrm{KCl}=$ Chlorine $47 \cdot 65$, potassium $52 \cdot 35=100$. But often containing impurities.
Pyr., etc.-B.B. in the platinum loop fuses, and gives a violet color to the outer flame. Added to a salt of phosphorus bead, which has been previously saturated with copper oxide, colors the O.F. deep azure-blue. Water completely dissolves it.

Obs.-Occurs at Vesuvius, about the fumaroles of the volcano. Also at Stassfurt; at Leopoldshall (leopoldite) ; at Kalusz, Galicia.

## XCERARGYRITE. Kerargyrite. Horn Silver. Silberhornerz, Germ.

Isometric. Cleavage none. Twins: twinning-plane octahedral. Usually massive and looking like wax; sometimes columnar, or bent columnar; often in crusts.
H. $=1-1 \cdot 5$. G. $=5.552$. Lustre resinous, passing into adamantine. Color pearl-gray, grayish-green, whitish, rarely violet-blue, colorless sometimes when perfectly pure; brown or violet-brown on exposure. Streak shining. Transparent-feebly subtranslucent. Fracture somewhat conchoidal. Sectile.

$$
\text { Comp. }-\mathrm{AgCl}=\text { Chlorine } 24 \cdot 7 \text {, silver } 75 \cdot 3=100 \text {, }
$$

Pyr., etc.-In the closed tube fuses without decomposition. B.B. on charcoal gives a globule of metallic silver. Added to a bead of salt of phosphorus, previously saturated with copper oxide, and heated in O.F., imparts an intense azure-blue to the flame. A fragment placed on a strip of zinc, and moistened with a drop of water, swells up, turns black, and finally is entirely reduced to metallic silver, which shows the metallic lustre on being pressed with the point of a knife. Insoluble in nitric acid, but soluble in ammonia.

Obs.-Occurs in veins of clay slate, accompanying other ores of silver, and usually only in the higher parts of these veins. It has also been observed with ochreous varieties of brown iron ore ; also with several copper ores, with calcite, barite, etc.

The largest masses are brought from Pern, Chili, and Mexico. Also occurs in Nicaragua near Ocotal; in Honduras. It was formerly obtained in the Saxon mining districts of Johanngeorgenstadt and Freiberg, but is now rare. Found in the Altai ; at Kongsberg in Norway; in Alsace; rarely in Cornwall, and at Huelgoet in Brittany. In Nevada, about Austin, Lander Co., abundant; at mines of Comstock lode. In Arizona, in the Willow Springs dist., veins of El Dorado cañon, and San Francisco dist. In Idaho, at the Poor Man lode.

Named from кर́pas, horn, and âprvoos, silver.
Calomel (Quecksilberhornerz, Germ.).-Composition $\mathrm{HgCl}=$ Chlorine $15 \cdot 1$, mercury 84.9 $<100$. Color white, grayish, brown. Spain.

Sal Ammoniac (Salmiak, Germ.).-Ammonium chloride, $\mathrm{NH}_{4} \mathrm{Cl}=$ Ammonium 33.7 , chlorine $66 \cdot 3=100$. Vesuvius, Etna, and many volcanoes.

NANTOKITE (Breithaupt). - Composition $\mathrm{CuCl}=$ Chlorine $35 \cdot 9$, copper $64 \cdot 1=100$. Cleavage cabic. Color white. Nantoko, Cnili.

Embolite.- $\mathrm{Ag}(\mathrm{Cl}, \mathrm{Br})$; the ratio of $\mathrm{Cl}: \mathrm{Br}$ varying from $3: 1$ to $1: 3$. Color grayishgreen. At various mines in Uhili; also Mexico ; Honduras.
Bromyrite, Bromargyrite (Bromsilber, Germ.).-Silver bromide, $\mathrm{AgBr}=$ Bromine $42 \cdot 6$, silver $57 \cdot 4=100$. Color when pure bright yellow, slightly greenish. Chili; Mexico.

Iodyrite, Iodargyrite (Iodsilber, Germ.). -Silver iodide, AgI = Yodine 54.0 , silver $46.0=$ 100. Color yellow. Mexico; Chili; Spain; Cerro Colorado mine in Arizona.

Tocornalite (Domeyko).-Composition AgI +HgI . Amorphous. Color pale yellow. Chañarcillo, Chili.

Cotunnite.-Lead chloride, $\mathrm{PbCl}_{2}=$ Chlorine $25 \cdot 5$, lead $74 \cdot 5=100$. Soft. White. Vesu nins. Pseudocotunnite (Scacchi), Vesuvius.

Molysite. --Composition $\mathrm{FeCl}_{6}=$ Chlorine $65 \cdot 5$, iron $34 \cdot 5=100$. Vesuvius,

## 2. HYDROUS CHLORIDES.

## CARNALLITE.

Massive, grarular ; flat planes developed by action of water, but no distinct traces of cleavage; lines of striæ sometimes distinguished, which indicate twin-composition.

Lustre shining, greasy. Color milk-white, but often reddish from mixture of oxide of iron. Fracture conchoidal. Soluble. Strongly phosphor escent.

Comp. $-\mathrm{KMgCl}_{3} .6 \mathrm{aq}=\mathrm{KCl}+\mathrm{MgCl}_{2}+6 \mathrm{aq}=\mathrm{Magnesium}$ chloride $34 \cdot 2$, potassium chloride $26 \cdot 9$, water $38 \cdot 9=100$.

The brown and red color of the mineral is due partly to iron sesquioxide, which is in hexagonal tables, and partly to organic matters (water-plants, infusoria, sponges, etc.).
Pyr., etc.-B. B. fuses easily. Soluble in water, 100 parts of water at $18.6^{\circ} \mathrm{C}$. taking up 6.5 parts.

Obs.-Occurs at Stassfurt, where it forms beds in the upper part of the salt formation, alternating with thinner beds of common salt and kieserite, and also mixed with the common salt. Its beds consist of subordinate beds of different colors, ređdish, bluish, brown, deep red, sometimes colorless. Sylvite occurs in the carnallite. Also found at Westeregeln; with salt at Maman in Persia. Its richness in potassium makes it valuable for exploration.

Tachiydirite. - Composition $\mathrm{CaMg}_{2} \mathrm{Cl}_{\mathrm{6}}+12 \mathrm{aq}=\mathrm{CaCl}_{2}+2 \mathrm{MgCl}_{2}+12 \mathrm{aq}$ ( Ramm .) $=$ Chlorine $40 \cdot 3$, magnesium 9.5 , calcium $7 \%$, water $42 \cdot 7=100$. Color yellowish. Deliquescent. Stassfurt.

Kremersite.-Probably $2 \mathrm{NH}_{4} \mathrm{Cl}+2 \mathrm{KCl}+\mathrm{FeCl}_{6}+3$ aq. Vesuvius
Erythrosiderite, also from Vesuvius, is $2 \mathrm{KCl}+\mathrm{FeCl}_{\mathrm{e}}+2 a q$.

## 3. OXYCHLORIDES.

## ATACAMITE.

Orthorhombic. $I \wedge I=112^{\circ} 20^{\prime}, O \wedge 1-\bar{\imath}=131^{\circ} 29^{\prime} ; \dot{c}: \bar{b}: \check{a}=1 \cdot 131$ $: 1 \cdot 492: 1$. Usually in modified rectangular prisms, vertically striated ; also in rectangular octahedrons. Twins: twinning-plane $I$; consisting of three individuals. Cleavage: $i-\check{\imath}$ perfect, $1-\bar{\imath}$ imperfect. Occurs also massive lamellar.
H. $=3-3 \cdot 5$. G. $=3 \cdot 761$ (Klein), $3 \cdot 898$ (Zepharovich). Lustre adamantinevitreous. Color various shades of bright green, rather darker than emerald, sometimes blackish-green. Streak apple-green. Translucent-subtrans lucent.

Comp.- $\mathrm{CuCl}_{2}+3 \mathrm{H}_{2} \mathrm{C=} \mathrm{O}_{2}=$ Chlorine $16 \cdot 64$, copper $59 \cdot 45$, oxygen $11 \cdot 25$, water $12 \cdot 66=100$. Also other compounds with more water ( 18 and $22 \frac{1}{2}$ p. c.).

Pyr., etc.-In the closed tube gives off much water, and forms a gray sublimate. B.B. on chaicoal fuses, coloring the O.F. azure-Blue, with a green edge, and giving two coatings, one brownish and the other grayish-white; continued blowing yields a globule of metallic copper; the coatings touched with the R.F. volatilize, coloring the flame azure-blue. In acids easily soluble.

Obs.-Occurs in different parts of Chili; in the district of Tarapaca, Bolivia; at Tocopilla in Bolivia; with malachite in South Australia; Serro do Bembe, near Ambriz, on the west coast of Africa; at the Estrella mine in southern Spain; at St. Just in Cornwall.

Tailingite.-Composition $\mathrm{CuCl}_{2}+4 \mathrm{H}_{2} \mathrm{CuO}_{2}+4 \mathrm{aq}$. In thin crusts. Color blue. Botallack mine, Cornwall.

Atelite.-Composition $\mathrm{CuCl}_{1}+2 \mathrm{H}_{2} \mathrm{CuO}_{2}+$ aq. Formed from tenorite. Vesuvius.
Percylite.-An oxychloride of lead and copper. Occurs in minute sky-blue cubes. Sonora, Mexico ; So. Africa.

MatLockite.-Composition $\mathrm{PbCl}_{2}+\mathrm{PbO}=$ Lead chloride 55.5 , lead oxide $44.5=100$. Cromford, near Matlock, Derbyshire.

Mendipite. --Composition $\mathrm{Pk} \mathrm{Cl}_{2}+2 \mathrm{PbO}=$ Lead chloride $38 \cdot 4$, lead oxide $61 \cdot 6=100$. In columnar masses, often radiatid. Color white. Mendip Hills, Somersetshire; Brillon, Westphalia.

Schwantzembergite.-Composition $\mathrm{Pb}(\mathrm{I}, \mathrm{Cl})_{2}+2 \mathrm{PbO}$. Color yellow. Desert of Atacama.

DAUBREITE.-Composition $\left(\mathrm{Bi}_{2} \mathrm{O}_{3}\right)_{4} \mathrm{BiCl}_{3}=\mathrm{Bi}_{2} \mathrm{O}_{3} 76 \cdot 16, \mathrm{BiCl}_{3} 23 \cdot 84=100$. Amorphous. Structure earthy, sometimes fibrous. Color yellowish-gray. H. $=2 \cdot 5$. G. $=6 \cdot 4-6 \cdot 5$. From the mine Constancia, Cerro de Tanza, Bolivia (Domeyko).

## IV. FLUORINE COMPOUNDS.

## 1. ANHYDROUS FLUORIDES.

## t fluorite or Fluor spar.* Flusspath, Germ.

Isımetric; forms usually cubic (sce f. 39, 40, 41, 52, 55, etc., pp. 10 to 19). Clearage: octahedral, perfect. Twins : twiming-plane, 1, f. 266, p. 91. Massive. Rarely columnar; usually granular, coarse or fine. Crystals often having the surfaces made up of small cubes, or cavernous with rectangular cavities.
$\mathrm{H} .=4 . \quad \mathrm{G} .=3 \cdot 01-3.25$. Lustre vitreous; sometimes splendent; usually glimmering in the massive varieties. Color white, yellow, green, rose, and crimson-red, violet-blue, sky-blue, and brown: wine-yellow, greenish and violet-blue,
 most common; red, rare. Streak white. Trans-parent-subtranslucent. Brittle. Fracture of fine massive varieties flatconchoidal and splintery. Sometimes presenting a bluish fluorescence. Phosphoresces when heated.

Comp., Var.-Calcium fluoride, $\mathrm{CaF}_{2}=$ Fluorine $48^{\prime 7}$, calciam $51 \cdot 3=100$. Berzelias found 0.5 of calcium phosphate in the fluorite of Derbyshire. The presence of chlorine was detected early by Scheele. Kersten found it in fluor from Marienberg and Freiberg. The bright colors, as shown by Kenngott, are lost on heating the mineral ; they are attributed mainly to different hydrocarbon compounds by Wyrouboff, the crystallization having taken place from aqueous solution.

Var. Ordinary; (a) cleavable or crystallized, very varions in colors; (b) coarse to fine granular; (c) earthy, dull, and sometimes very soft. A soft earthy variety from Ratofka, Russia, of a lavender-blue color, is the ratofkite. The finely-colored fluorites have been called, according to their colors, false ruby, topaz, emerald, amethyst, etc. The colors of the phosphorescent light are various, and are independent of the actual color; and the kind affording a green color is (d) the chlorophane.

Pyr., etc.-In the closed tube decrepitates and phosphoresces. B.B. in the forceps and on charcoal fuses, coloring the flame red, to an enamel which reacts alkaline to test paper. With soda on platinum foil or charcoal fuses to a clear bead. becoming opaque on cooling ; with an excess of soda on charcoal yields a residue of a difficultly fusible enamel, while most of the soda sinks into the coal ; with gypsum fuses to a transparent bead, becoming opaque on cooling. Fused in an open tube with fused salt of phosphorus gives the reaction for fluorine. Treated with sulphuric acid gives fumes of hydrofluoric acid which etch glass. Phom
phorescence is obtained from the coarsely powdered spar below a red heat. At a high tem. perature it ceases, but is partially restored by an electric discharge.

Diff.-Recognized by its octahedral cleavage, its etching power when heated in the glasa tube, etc.

Obs.-Sometimes in beds, but generally in veins, in gneiss, mica slate, clay slate, and also in limestones, both crystalline and uncrystalline, and sandstones. Often occurs as the gangue of metallic ores. In the North of England, it is the gangue of the lead veins. In Derby. shire it is abundant, and also in Cornwall. Common in the mining district of Saxony; fine near Kongsberg in Norway. In the dolomites of St. Gothard it occurs in pink octahedrons

Some American localities are: Trumbull and Plymouth, Conn. ; Muscolonge Lake, Jefferson Co., N.Y., in gigantic cubes ; Rossie, St. Lawrence Co. ; near the Franklin furnace, N. J. ; Gallatin Co., Ill.; Thunder Bay, Lake Superior; Missouri.

Seliatite (Strüver).-Magnesium fluoride, MgF $\mathbf{2}_{2}$. Tetragonal. Colorless. Occurs with anhydrite at Gerbulaz in Savoy.

Yttrocerite. - Composition $2\left(9 \mathrm{CaF}_{2}+2 \mathrm{YF}_{2}+\mathrm{CeF}_{2}^{\prime}\right)+3 \mathrm{aq}$ ( Ramm .). Color violet-blue, white. Near Fahlun, Sweden ; Amity, N. Y. ; Paris, Me. ; etc.
Fluocerite.-Contains (Berzelius) $\mathrm{CeO}_{3} 82 \cdot 64$, YO 1.12. Sweden.
Fluellite.-Contains (Wollaston) fluorine and aluminum. Cornwall.
Cryptohalite.-Fluosilicate of ammonium. Vesuvius. Also observed at Vesuvius, kydrofluorite, HF, and proidonite, $\mathrm{SiF}_{4}$ (Scacchi).

## CRYOLITE.*

Triclinic (DesCloizeaux and Welsky). Form approaching very closely in appearance and angles to the cube and cubo-
 octahedron of the isometric system. (ienneral habit as in f. $460 ; P(O) \wedge T(I)=90^{\circ} 2^{\prime}, P(O) \wedge M\left(I^{\prime}\right)$ $=90^{\circ} 24^{\prime}, M \wedge T\left(I \wedge I^{\prime}\right)=91^{\circ} 57^{\prime} ;$ also $l\left(1-\iota^{\prime}\right) \wedge M$ $\left(I^{\prime}\right)=124^{\circ} 30^{\prime}, l\left(1-\imath^{\prime}\right) \wedge T(I)=124^{\circ} 14^{\prime}$ (angles by Websky). Twins common. Cleavage parallel to the three planes $P, M, T$; in crystals most complete parallel to $T$, in masses parallel to $P$. Commonly massive, cleavable.
H. $=2 \cdot 5$. G. $=2 \cdot 9-3 \cdot 0 ヶ 7$. Lustre vitrenus; slightly pearly on $O$. Color snow-white ; sometimes reddish or brownish to brick-red and even black. Sub-transparent-translucent. Immersion in water increases the transparency. Brittle.

Vomp. $-\mathrm{Na}_{6} \mathrm{AlF}_{12}\left(\right.$ or $\left.6 \mathrm{NaF}+\mathrm{AlF}_{6}\right)=$ Aluminum $13 \cdot 0$, sodium $32 \cdot 8$, fluorine $54 \cdot 2=100$.
Pyr., etc.-Fusible in the flame of a candle. B.B. in the open tube heated so that the flame enters the tube, gives off hydrofluoric acid. etching the glass; the water which condenses at the upper end of the tube reacts for fluorine with Brazil-wood paper. In the forceps fuses very easily, coloring the flame yellow. On the charcoal fuses easily to a clear bead, which on cooling becomes opaque; after long blowing, the assay spreads out, the sodium fluoride is absorbed by the coal, a suffocating odor of fluorine is given off, and a crust of alumina remains, which, when heated with cobalt solution in O.F., gives a blue color. Soluble in sulphuric acid, with evolution of hydrofluoric acid.

Diff.-Distinguished by its extreme fusibility, and its yielding hydrofluoric acid in the open tabe.

Obs.-Occurs in a bay in Arksut-fiord, in West Greenland, at Evigtok, where it constitutes a large bed or vein in gneiss. It is used for making soda, and soda and alumina salts; also in Pennsylvania, for the manufacture of a white glass which is a very good imitation of porcelain.

Chiolite.-G. $=2 \cdot 84-2 \cdot 90 . \mathrm{Na}_{3} \mathrm{AlF}_{9}\left(\right.$ or $\left.3 \mathrm{NaF}+\mathrm{AlF}_{6}\right)$. Chodneffite.-G. $=3 \cdot 01 . \mathrm{Na}_{4} \mathrm{Al}$ $\mathrm{F}_{10}$ (or $4 \mathrm{NaF}+\mathrm{AlF}_{6}$ ) Ramm. The two minerals are alike in physical characters, occurring in minute tetragonal pyramids ; both from Miask.

## 2. HYDROUS FLUORIDES.

## PACHNOLITE. Thomsenolite.*

Monoclinic, with the lateral axes equal ("clino-quadratic" Nordens kiöld). $\dot{c}: b: c \grave{c}=1.044: 1: 1 ; C=92^{\circ} 30^{\prime}$. Prisms slender, a little tapering ; $I$ horizontally striated. Cleavage: basal very perfect. Also massive, opal or chalcedony-like.
H. $=2 \cdot 5-4 . \quad$ G. $=2 \cdot 929-3 \cdot 008$, of crystals. Lustre vitrenus, of a cleavage-face a little pearly, of massive waxy. Color white, or with a reddish tinge. Transparent to translucent.

Comp. $-\mathrm{Na}_{2} \mathrm{Ca}_{2} \mathrm{AlF}_{12}+2 \mathrm{aq}$, or $2 \mathrm{NaF}+2 \mathrm{CaF}_{2}+\mathrm{AlF}_{6}+2 \mathrm{aq}=$ Fluorine 51.28 , aluminum $12 \cdot 28$, calcium $17 \cdot 99$, sodium $10 \cdot 35$, water $8 \cdot 10=100$.

Pyr., etc.-Fuses more easily than cryolite to a clear glass. The massive decrepitates remarkably in the flame of a candle. In powder easily decomposed by sulphuric acid.

Obs.-Found incrusting the cryolite of Greenland, and a result of its alteration. The crystals often have an ochre-colored coating, especially the
 terminal portion; they are sometimes quite large, and have much the appearance of cryolite. The mineral was first described by Knop, and though his descripticn of the crystals does not agree with that given above, there seems to be no doubt that the material was the same, which has since been investigated by Hagemann (dimetric pachnolite $=$ thomsenolite), Wöhler (pyroconite) and Kœnig, as urged by the latter.

Knop originally described two varieties of the mineral, to which he gave the name pachnolite. The variety, A, appeared in large, cuboidal crystals, with cleavage planes parallel to the faces, intersecting at angles of approximately $90^{\circ}$. These cleavage planes seemed to be continued on into the mass of the cryolite on which the crystals were implanted. The second variety, B, was in small brilliant crystals, of prismatic form, grouped together often in parnullel position upon the cryolite (hence the name, from $\pi \alpha \dot{\alpha} \nu \eta$, frost). The identity of the two varieties chemically was shown by the analyses of Knop and Wöhler. The crystals of variety B, according to Knop, had $I \wedge I=81^{\circ} 24^{\prime}$, etc.

Knop has recently (Jahrb. Min., 1876, 849) suggested the possibility that the crystals of "cryolite," upon which Websky obtained the angles quoted on the preceding page, were really identical with variety A of pachnolite. The crystallographio relation of the two species is not yet clearly made out.

Arksutite, Hagemannite, Gearksutite, all from Greenland; and Prosopite, from Altenberg.-Fluorine minerals, related to those which precede, but whose exact nature is not yet known.

Ralstonite (Brush).-An hydrous aluminum fluoride, containing also a little magnesium and sodium. Occurs in minute regular octahedrons on the cryolite from Greenls nd.

## V. OXYGEN COMPOUNDS.

## 1. OXIDES of Metals of the Gold, Iron, or 'lin Groups.

A. 'ANHYDROUS OXIDES.<br>(a) Protoxides, $\stackrel{\mathrm{If}}{\mathrm{R}} \mathrm{O}$ (or $\stackrel{\mathrm{r}}{\mathrm{R}_{2}} \mathrm{O}$ ).

CUPRITE. Red Copper Ore. Rothkupfererz, Germ.
Isometric (see figures on p. 17). Cleavage: octahedral. Sometimes cubes lengthened into capillary forms. Also
 massive, granular; sometimes earthy.
$\mathrm{H}_{.}=3 \cdot 5-4$. G. $=5 \cdot 85-6 \cdot 15$. Lustre adamantine or submetallic to earthy. Color i'ed, of various shades, particularly cochineal-red; occasionally crimson-red by transmitted light Streak several shades of brownish-red, shin ing. Subtransparent-subtranslucent. Frao ture conchoidal, uneven. Brittle.

Comp., Var.- $\mathrm{Cu}_{2} \mathrm{O}=$ Oxygen 11 $\cdot 2$, copper $88 \cdot 8=100$ Sometimes affords traces of selenium. Chalcotvichite is a variety which occurs in capillary or acicular crystallizations, which are cubes elongated in the direction of the octahedral axis. It also occurs earthy; lite Ore (Ziegelerz Germ.). Brick-red or reddish-brown and earthy, often mixed with red oxide of iron; sometimes nearly black.
Pyr., etc.-Unaltered in the closed tube. B.B. in the forceps fuses and colors the flame emerald-green; if previously moistened with hydrochloric acid, the color imparted to the Hlame is momentarily azure-blue from copper chloride. On charcoal first blackens, then fuses, and is reduced to metallic copper. With the fluxes gives reactions for copper oxide. Soluble in concentrated hydrochloric acid.

Obs.-Occurs in Thuringia ; on Elba, in cubes ; in Cornwall ; in Devonshire; in isolated crystals, in lithomarge, at Chessy, near Lyons, which are generally coated with malachite, etc. At the Somerville, and Flemington copper mines, N. J. ; at Cornwall, Lebanon Co., Pa.; in the Lake Superior region.

Hidmocuprite (Genth).-A hydrous cuprite. Occurs in orange-yellow coatings on mregnetite. Cornwall, Lebanon Co., Pa.

Iexagonat.zincite. Red Zinc Ore. Rothzinkerz, Germ.
Hexagonal. $O \wedge 1=118^{\circ} 7^{\prime} ; \dot{c}=1 \cdot 6208$. In quartzoids with truncated summits, and prismatic faces I. Geavage: basal, eminent; prismatic, sometimes distinct. Usual in foliated grains or coarse particles and masses; also granular.
H. $=4-4 \cdot 5 . \quad$ G. $=5 \cdot 43-5 \cdot 7$. Lustre subadamantine. Streak orange-jellow. Color deep red, also orange-yellow. Translucent-subtranslucent. Fracture subconchoidal. Brittle.

[^34]Pyr., etc.-Heated in the closed tube blackens, but on cooling resumes the original color. B. B. infusib.e; with the fluxes, on the platinum wire, gives reactions for manganese, and on charcoal in R.F. gives a coating of zinc oxide, yellow while hot, and white on cooling. The coating, mcistened with cobalt solution and treated in R.F., assumes a green color. Soluble in acids without effervescence.

Obs.-Occurs with franklinite and also with calcite at Stirling Hill and Mine Hill, Sussex Co., N. J.

Calcozincite.-Impure zincite (mixed with $\mathrm{CaCO}_{3}$, etc.). Stirling Hill, N. J.

## tenorite.* Melaconite. Schwarzkupfererz (Kupferschwärze), Germ.

Orthorhombic (tenorite), crystals from Vesuvius. Earthy ; massive ; pulverulent (melaconite); also in shining flexible scales; also rarely in cubes with truncated angles (psendomorphous?).
$\mathrm{H} .=3$. G. $=6 \cdot 25$, massive (Whitney). Lustre metallic, and color steel or iron-gray when in thin scales; dull and earthy, with a black or grayishblack color, and ordinarily soiling the fingers when massive or pulverulent.

Comp.- $\mathrm{CuO}=$ Oxygen $20 \cdot 15$, copper $79 \cdot 85=100$
Pyr., etc.-B.B. in O.F. infusible ; other reactions as for cuprite (p. 244). Soluble in hydrochloric and nitric acids.

Obs.-Found on lava at Vesuvius in minute scales; and also pulverulent (Scacchi, who uses the name melaconise for the mineral). Common in the earthy form (melaconite) about copper mines, as a result of the decomposition of chalcopyrite and other copper ores. Ducktown mines in Tennessee, and Keweenaw Point, L. Superior.

Periclasite.-Essentially magnesium oxide, MgO, or more exactly ( $\mathrm{Mg}, \mathrm{Fe}$ ) O, where $\mathrm{Mg}: \mathrm{Fe}=20: 1$, or $30: 1$. Mt. Somma.

Bunsemite.-NiO. Found at Johanngeorgenstadt. The compound MnO has been found recently in Wermland, in masses of a green color, and with cubic cleavage. See manganosite, p. 431.

MAssicot (Bleiglätte).- PbO, bnt generally impure. Badenweiler, Baden. Mexico. Anstin's mines, Va .

Hydrargyrite.- HgO ; with Bordosite, $\mathrm{AgCl}+\mathrm{HgCl}$, at Los Bordos, Chili.

## (b) Sesquioxides. General Formula $\mathrm{RO}_{3}$ CORUNDUM.*

Rhombohedral. $R \wedge R=86^{\circ} 4^{\prime}, O \wedge 1(R)=122^{\circ} 26^{\prime} ;\left(122^{\circ} 25^{\prime}\right.$, Kojk scharof) ; $\dot{c}=1 \cdot 363$. Cleavage: basal, sometimes perfect, but interrupted, commonly imperfect in the blue variety; rhombohedral, often perfect. Large crystals usially rough. Twins: composition-face $\tilde{R}$. Also massive granular or impalpable; often in layers from composition parallel to $R$.
$\mathrm{H} .=9$. G. $=3 \cdot 909-4 \cdot 16$. Lustre vitreous; sometimes pearly on the basal planes, and occasionally exhibiting a bright opalescent star of six rays in the direction of the axis. Color blue, red, yellow, brown, gray, and nearly wh ite; streak uncolored. Transparent-translucent. Fracture conchoidal - uneven. Exceedingly tough when compact.


Comp., Var--Pure alumina $\mathrm{AlO}_{3}=$ Oxygen 46.8 , aluminum $53 \cdot 2=100$. There are three
sulbdivisions of the species prominently recognized in the arts, and until early in this centary regarded as distinct species; but which actually differ only in purity and state of crystallization or strusture.

Vak. 1. Sappiile - Includes the purer kinds of fine colors, transparent to translucent, useful as gems. Stones are named according to their colors; true Ruby, or Oriental Ruby, red; O Topd yellow ; O. Emerald, green; O. Amethyst, purple.
2. Corundum.-Includes the kinds of dark or dull colors and not transparent, colors light blue to gray, brown, and black. The original adamantine spar from India has a dark grayish smoky-brown tint, but greenish or bluish by transmitted light, when translucent, and either in distinct crystals often large, or cleavable-massive. It is ground and used as a polishing material, and being purer, is superior in this respect to emery. It was thus employed in ancient times, both in India and Europe.
3. Emerx, Schmirgel, Germ.-Includes granular corundum, of black or grayish-black color, and contains magnetite or hematite intimately mixed. Feels and looks much like a black fine-grained iron ore, which it was long considered to be. There are gradations from the evenly fine-grained emery to kinds in which the corundum is in distinct crystals. This last is the case with part of that at Chester, Massachusetts.

Pyr., etc.-B.B. unaltered; slowly dissolved in borax and salt of phosphorus to a clear glass, which is colorless when free from iron ; not acted upon by soda. The finely pulverized mineral, after heating with cobalt solution, gives a beautiful blue color. Not acted upon by acids, but converted into a soluble compound by fusion with potassium bisulphate or soda. Friction excites electricity, and in polished specimens the electrical attraction continues for a considerable length of time.

Diff.-Distinguished by its hardness, scratching quartz and topaz; its infusibility and its high specific gravity.

Obs.-This species is associated with crystalline rocks, as granular limestone or dolomite, gneiss, granite, mica slate, chlorite slate. The fine sapphires are usually obtained from ths beds of rivers, either in modified hexagonal prisms or in rolled masses, accompanied by grains of magnetic iron ore, and several species of gems. The emery of Asia Minor, according to Dr. Smith, occurs in granular limestone.

Sapphires occur in Ceylon; the East Indies; China Corundum, at St. Gothard ; in Piedmont; Urals; Bohemia. Emery is found in large boulders on some of the Grecian islands ; also in Asia Minor, near Fphesus, etc. In N. America, in Mnssachusetts, at Chester, corundum and emery in a large vein; also in Westchester Co., N. Y. In New York, at Warwiok and Amity. In Pennsylvania, in Delaware Co., and Chester Co. In western N. Carolina, at many localities in large quantities, and sometimes in crystals of immense size. In Georgia, in Cherokee Co. In California, in Los Angeles Co.; in the gravel on the Upper Missouri' River in Montana.
hematite. Specular Iron. Eisenglanz, Rotheisenerz, Germ.
Rhombohedral. $\quad R \wedge R=86^{\circ} 10^{\prime}, \quad O \wedge R=122^{\circ} 30^{\prime} ; \dot{c}=1 \cdot 3591$. () $\wedge \frac{4}{3}-2=118^{\circ} 53^{\prime}, O \wedge 1^{3}=103^{\circ} 32, R \wedge \frac{4}{3}-2=154^{\circ} 2^{\prime}$. Clearage : parallel to $R$ and $O$; often indistinct. Twins: twinning-plane $R$; also $O$

(f. 267, p. 91). Also columnar-granular, botryoidal, and stalactitic shapes also lameliar, laminæ joined parallel to $O$, and variously bent, thick ur thin; also granular, friable or compact.
$\mathrm{H} .=5 \cdot 5-6 \cdot 5 . \quad \mathrm{G} .=4 \cdot 5-5 \cdot 3$; of some compact varieties, as low as $4 \cdot 2$. Lustre metallic and occasionally splendent ; sometimes earthy. Color dark steel-gray or iron-black; in very thin particles blood-red by transmitted light; when earthy, red. Streak cherry-red or reddish-brown. Opaque, except when in very thin laminæ, which are faintly translucent and bloodred. Fracture subconchoidal, uneven. Sometimes attractable by the magnet, and occasionally even magnetipolar.
Comp., Var.-Iron sesquioxide, $\mathrm{FeO}_{3}=$ Oxygen 30 , iron $70=100$. Sometimes containios titanium and magnesium.
The varieties depend on texture or state of aggregation, and in some cases the presence :impurities.

Var. 1. Specular. Lustre metallic, and crystals often splendent, whence the name specular iron. (b) When the structure is foliated or micaceous, the ore is called micaceous hematito (Eisenglimmer). 2. Compact columnar; or fibrous. The masses often long radiating ; lustre submetallic to metallic ; color brownish-red to iron-black. Sometimes called $r_{t} d$ hematite, the name hematite among the older mineralogists including the fibrous, stalactitic, and other solid massive varieties of this species, limonite, and turgite. 3. Red Ochreous. Red and earthy. Often specimens of the preceding are red ochreous on some parts. Reddle and red chalk are red ochre, mixed with more or less clay. 4. Clay Iron-stone; Argillaceous hematite. Hard, brownish-black to reddish-brown, heavy stone ; often in part deep-red; of submetallic to unmetallic lustre; and affording, like all the preceding, a red streak. It consists of iron sesquioxide with clay or sand, and sometimes other impurities.

Pyr., etc.-B.B. infusible; on charcoal in R.F. becomes magnetic; with borax in O.F. gives a bead, which is yellow while hot and colorless on cooling; if saturated, the bead appears red while hot and yellow on cooling ; in R.F. gives a bottle-green color, and if treated on charcoal with inetallic tin, assumes a vitriol-green color. With soda on charcoal in R.F. is reduced to a gray magnetic metallic powder. Soluble in concentrated hydrochloric acid.
Diff.-Distinguished from magnetite by its red streak, also from limonite by the same means, as well as by its not containing water ; from turgite by its greater hardness and by its not decrepitating B.B. It is hard; and infusible.

Obs.-This ore occurs in rocks of all ages. The specular variety is mostly confined to crystalline or metamorphic rocks, but is also a result of igneous action about some volcanoes, as at Vesuvius. Traversella in Piedmont; the island of Elba, afford fine specimens; also St. Gothard, often in the form of rosettes (Eiservose, and Cavradi in Tavetsch; and near Limoges, France. At Etna and Vesuvius it is the result of volcanic action. Arendal in Norway, Longban in Sweden, Framont in Lorraine, Dauphiny, also Cleator Moor in Cumberland, are other localities.

In $N$. America, widely distributed, and sometimes in beds of vast thickness in rocks of the Archæan age, as in the Marquette region in northern Michigan; and in Missouri. at the Pilot Knob and the Iron Mtn.; in Arizona and New Mexico. Some of the localities, interesting for their specimens, are in northern New York, etc.; Woodstock and Aroostook, Me.; at Hawley, Mass. ; at Piermont, N. H.

This ore affords a considerable portion of the iron manufacturedin different countries. The varieties, especially the specular, require a greater degree of heat to melt than other ores, but the iron obtained is of good quality. Pulverized red hematite is employed in polishing metals, and also as a coloring material. The fine-grained massive variety from England (bloodstone), showing often beautiful conchoidal fracture, is mach used for burnishing metals. Red ochre is valuable in making paint.

Martite is iron sesquioxide under an isometric form, occurring in octahedrons or dodecahedrons like magnetite, and supposed to be pseudomorphous, mostly after magnetite. H. = 6-7. G. $=4 \cdot 809-4 \cdot 832$, Brazil, Breith. ; $5 \cdot 33$, Monroe, N. Y., Hunt. Lustre submetallic. Color iron-black, sometimes with a bronzed tarnish. Streak reddish-brown or purplish-brown. Frasture conchoidal. Not magnetic. or only fecbly so. The crystals are sometimes inbedded in the massive sesquioxide. They are distinguished from magnetite by their red streak, and very feeble, if any, action on the magnetic needle.

Fonnd in Vermont at Chittenden; in the Marquette iron region south of L. Superior; Bass lake, Canada West; Digby Neck, Nova Scotia; at Monroe, N. Y. ; in Moravia, neal Schönberg, in granite.
menaccanite.* Ilmenire. Titanic Iron Ore. Titaneisen, Geim.
Rhombohedral ; tetartohedral to the hexagonal type. $R \wedge R=85^{\circ} 30^{\prime}$

56" (Koksch.), $\dot{c}=1.38458$. Angles nearly as in hematite. Often a cleavage parallel with the terminal plane, but 470 probably due to planes of composition. Crystals
 usually tabular. Twins: twinning-plane $O$; sometimes producing, when repeated, a form resembling f. 468. Often in thin plates or laminæ; massive; in loose grains as sand.
$\mathrm{H} .=5-6$. G. $=4 \cdot 5-5$. Lustre submetallic. Color iron-black. Streak submetallic, powder black to brownish-red. Opaque. Fracture conchoidal. Influences slightly the magnetic needle.

Comp., Var.-( $\left.\mathrm{Ti}, \mathrm{Fe}_{2}\right)_{2} \mathrm{O}_{3}$ (or hematite, with part of the iron replaced by titanium), the proportion of Ti to Fe varying. Mosander assumes the proportion of $\mathrm{FeO}: \mathrm{TiO}_{2}$ to be always $1: 1$, and that in addition variable amounts of $\mathrm{FeO}_{3}$ are present in the different varieties. The extensive investigations of Rammelsberg have led him to write the formula like Mosan$\operatorname{der}\left(\mathrm{FeO}, \mathrm{TiO}_{2}\right)+\mathrm{nFeO}$ ( notice here that $\mathrm{FeO}, \mathrm{TiO}_{2}=\mathrm{RO}_{3}$ ). This method has the advantage of explaining the presence of the magnesium, occurring sometimes in considerable amount, it replacing the iron ( FeO ). The first formula given requires the assumption of $\mathrm{Mg}_{2} \mathrm{O}_{3}$. Friedel and Guerin have recently discussed the same subject (Ann. Ch. Phys., V., viii., 38, 1876).

Sometimes contains manganese. The varieties recognized arise mainly from the proportions of iron to titanium. No satisfactory external distinctions have yet been made out.

The following analyses will illustrate the wide range in composition:


Pyr., etc.-B.B. infusible in O.F. although slightly rounded on the edges in R.F. With borax and salt of phosphorus reacts for iron in O.F., and with the latter flux assumes a more or less intense brownish-red color in R.F.; this treated with tin on charcoal changes to a violet-red color when the amount of titanium is not too small. The pulverized mineral, heated with hydrochloric acid, is slowly dissolved to a yellow solution, which, filtered from the undecomposed mineral and boiled with the addition of tin-foil, assumes a beautiful blue or violet color. Decomposed by fusion with sodium or potassium bisulphate.

Diff.-Resembles hematite, but has a submetallic, nearly black, streak.
Obs.-Some of the principal European localities of this species are: Krageröe, Egersund, Arendal, Norway; Uddewalla, Sweden ; Ilmen Mts. (ilmenite) ; Iserwiese, Riesengebirge (iserine) ; Aschaffenburg; Eisenach; St. Cristophe (crichtonite).
Occurs in Warwick, Amity, and Monroe, Orange Co., N. Y.; also near Edenville ; at Chester and South Royalston, Mass. ; at Bay St. Paul in Canada; also with labradorite at Château Richer. Grains are found in the gold sands of Califorria.

## PEROFSKITE.*

Isometric, Rose (fr. Ural). Habit cubic, with secondary planes incompletely developed; in cubes, octahedrons, and cubo-octahedrons, from Arkansas. Twins: twinning-plane octahedral, Magnet Cove, Ark.; also like f. 276 , p. 93 , Achmatorsk. Cleavage: parallel to the cubic faces rather perfect.
$\mathrm{H} .=5 \cdot 5 . \quad \mathrm{G} .=4 \cdot 02-4 \cdot 04$. Lustre metallic-adamantine. Color pale yelow, honey-yellow, orange-ycllow, reddish-brown, grayish-black to ironblack. Streak colorless, grayish. Transparent to opaque. Double refract. ing.

Comp.- $(\mathrm{Ca}+\mathrm{Ti}) \mathrm{O}_{3}=\mathrm{RO}_{3}=$ Titanic oxide $59 \cdot 4$, lime $40 \cdot 6=100$.
Pyr., etc.-In the forceps and on charcoal infusible. With salt of phosphorus in U.F. dis Rolvps easily, giving a bead greenish while hot, which becomes colorless on cooling; in R.F. the lead changes to grayish-green, and on cooling assumes a violet-blue color. Entirely decomposed by boiling sulphuric acid.

Obs.-Occurs at Achmatovsk, in the Ural ; in the valley of Zermatt ; at Wildkreuzjoch in the Tyrol. Also at Magnet Cove, Arkansas.

DesCloizeaux has found that the yellow crystals from Zermatt have a complex twinned structure, and are optically biaxial. Kokscharof, in his latest investigations, has shown that the Russian specimens also exhibit phenomena in polarized light analogous to those of biaxial crystals, though irregular. He proves, however, that crystallographically the crystals examined by him were unquestionably isometric, and adds also that almost all the Russian perofskite crystals are penetration-twins. The latter fact explains the commonly observed striations on the cubic planes, as also the incompleteness in the development of the other forms. He refers the optical irregularities to the want of homogeneity in the crystals. DesCloizeaux speaks of inclosed lamellæ of a doubly-refracting substance analogous to the parasite in boracite crystals (p. 176).
Hydrotitanite. - A decomposition-product of perofskite crystals from Magnet Cove, Arkansas. Form retained but color changed to yellowish-gray (Kœnig).
(c) Compounds of Protoxides and Sesquioxides,* $\mathrm{RRO}_{4}$ (or $\mathrm{RO}+\mathrm{RO}_{3}$ ).

## Spinel Group. Isometric (Octahedral).

SPINEL.
Isometric. Habit octahedral. Faces of octahedron sometimes convex. Cleavage : octahedral. Twins: twinning-plane 1.
$\mathrm{H} .=\mathrm{S} . \quad \mathrm{G} .=3 \cdot 5-4 \cdot 1$. Lustre vitreous; splendentnearly dull. Color red of various shades, passing into blue, green, yellow, brown, and black; occasionally almost white. Streak white. Transparent-nearly opaque. Fracture conchoidal.

Comp., Var.-The spirels proper have the formula $\left.\mathrm{Mg}_{\mathrm{AlO}}^{4} \mathbf{(}\right)=\mathrm{MgO}$ $+\mathrm{AlO}_{3}$ ), or in other words contain chiefly magnesium and aluminum, with the former replaced in part by iron ( Fe ), calcium ( Ca ), and manganese ( Mn ) ; and the latter by iron ( Fe ). There is hence a gradation into kinds containing little or no magnesium, which stand as
 distinct species, viz., Hercynite and Galnite. $\mathrm{Mg}_{\mathrm{AlO}}^{4} \mathbf{=}=$ Alumina 72 , magnesia $28=100$.

Var. 1. Ruby, or Magnesia Spinel.-Clear red or reddish; transparent to translucent; sometimes subtranslucent. G. $=3.52-3 \cdot 58$. Composition $\mathrm{MgAlO}_{4}$, with little or no Fe , and sometimes chromium as a source of the red color. 2. Ceylonite, or Iron-Magnesia Spinel. Color dark-green, brown to black, mostly opaque or nearly so. G. $=3 \cdot 5-3 \cdot 6$. Composition $\mathrm{Mg}+1 \mathrm{O}_{4}+\mathrm{Fe} . \mathrm{HlO}_{4}$. Sometimes the Al is replaced in part by Fe . 3. Picotite. Contains over $7 \mathrm{p} . \mathrm{c}$. of chromium oxide. Color black. Lustre brilliant. G. $=4 \%$. The original was from a rock occurring about L. Lherz, called Lherzolite.

Pyr., etc.-B.B. alone infusible; the red variety turns brown, and even black and opaque, as the temperature increases, and on cooling becomes first green, and then nearly colorless, and at last resumes the red color. Slowly soluble in borax, more readily in salt of phosphorus, with which it gives a reddish bead while hot, becoming faint chrome-green on

[^35]cooling. 'The black varieties give reactions for iron with the fluxes. Soluble with difficulty in concentrated sulphuric acid. Decomposed by fusion with sodium or potassium bisulphate.

Diff.-Distinguished by its octahedral form, hardness, and infusibility; magnetite in attracted by the magnet, and zircon has a higher specific gravity.

Obs.-Spinel occurs imbedded in granular limestone, and with calcite in serpentine, gneiss, nnd allied rocks. It also occupies the cavities of masses ejected from some volcanoes, e.g., Mt. Somma.

Fine spinels are found in Ceylon; in Siam, as rolled pebbles in the channels of rivers Oconr at Aker in Sweden ; also at Monzoni in the Fassathal.

From Amity, N. Y., to Andover, N. J., a distance of about 30 miles, is a region of granula limestone and serpentine, in which localities of spinel abound; numerous about Warwick, and at Monroe and Cornwall. Franklin, Sterling, Sparta, Hainburgh, and Vernon, N. J., are other localities. At Antwerp, Jefferson U.o., N. Y.; at Bolton and elsewhere in Mass.

Hercyntte. - $\mathrm{FeAlO}_{4}$ ( or $\mathrm{FeO}+\mathrm{AlO}_{3}$ ). Color black. Massive. Bohemia.
Jacobsite (Damour).- $\mathrm{RRO}_{4}$, or $(\mathrm{Mn}, \mathrm{Mg})(\mathrm{Fe}, \mathrm{Mn}) \mathrm{O}_{4}$. Color deep black. Occurs in dis. torted octahedrons (magnetic) in a crystalline limestone at Jacobsberg, Sweden.

## GAHNITE. Zinc Spinel.

Isometric. In octahedrons, dodecahedrons, etc., like spinel.
$\mathrm{H} .=7 \cdot 5-8$. G. $=4-4 \cdot 6$. Lustre vitreous, or somewhat greasy. Color dark green, grayish-green, deep leek-green, greenish-black, bluish-black, yellowish- or grayish-brown ; streak grayish. Subtranslucent to opaque.

Comp., Var.- $\mathrm{Zn}_{\mathrm{AlO}}^{4}$ = Alumina $61 \cdot 3$, oxide of zinc $38 \cdot 7=100$; with little or no magnesium. The zinc sometimes replaced in small part by manganese or iron ( $\mathrm{Mn}, \mathrm{Fe}$ ), and the aluminum in part by iron ( fe ).

Var. 1. Automolite, or Zinc Galnite; with sometimes a little iron. G. $=4 \cdot 1-4 \cdot 6$. Colors as above given. 2. Dysluite, or Zinc-Manganese-Iron Gahnite. Composition (Zn, Fe,Mn) ( $\mathrm{tl}, \mathrm{Fe}$ ) $\mathrm{O}_{4}$. Color yellowish-brown or grayish-brown, G. =4-4.6. Form the octahedron, or the same with truncated edges. 3. Kreittonite, or Zinc-Iron Galnite. Composition (Zn, $\mathrm{Fe}, \mathrm{Mg})\left(\mathrm{z}+\mathrm{l}, \mathrm{Fe} ; \mathrm{O}_{4}\right.$. Occurs in crystals, and granular massive. $\mathrm{H} .=7-8$. G. $=4 \cdot 48-4 \cdot 89$. Color velvet to greenish-black; powder grayish-green. Opaque.

Pyr., etc.-Gives a coating of zinc oxide when treated with a mixture of borax and soda on charcoal. Otherwise like spinel.

Obs.-Automolite is found at Fahlun, Sweden; Franklin, N. Jersey; Canton mine, Ga. ; Inysluite at Sterling, N. J. ; Kreittonite at Bodenmais in Bavaria.

MAGNETITE. Magnetic Iron Ore. Magneteisenstein, Magneteisenerz, Germ.
Isometric. The octahedron and dodecahedron the most common forms,



Achmatovsk.

475


Haddam.

Kig. 475 is a distorted dodecahedron. Cleavage: octahedral, perfect to
imperfect. Drdecahedral faces commonly striated parallel to the longer diagonal. Twins: twi - ng-plane, 1; also in dendrites, branching at angles of $60^{\circ}$ (f. 277, p. y3), Massive, structure granular-particles of various sizes, sometimes impalpacle.
H. $=\breve{5} \cdot 5-6 \cdot 5$. G. $=4.9-5 \cdot 2$. Lustre metallic-submetallic. Colur iron black; streak black. Opaque; but in mica sometimes transparent or nearly so ; and varying from almost colorless to pale smoky-brown and black. Fracture subconchoidal, shining. Brittle. Strongly magnetic. sometimes possessing polarity.

Comp., Var. $-\mathrm{FeFeO}_{4}$ (or $\mathrm{Fe}_{3} \mathrm{O}_{4}$ ) $=\mathrm{FeO}+\mathrm{FeO}_{3}=$ Oxygen $27 \cdot 6$, iron $72 \cdot 4=100$; or iron sesquioxide $68 \cdot 97$, iron protoxide $31 \cdot 03=100$. The iron sometimes replaced in small part by magnesium. Also sometimes titaniferous.
From the normal proportion of Fe to $\mp \mathrm{e}, 1: 1$, there is occasionally a wide variation, and thus a gradual passage to the sesquioxide $\mathrm{FeO}_{3}$; and this fact may be regarded as evidence that the octahedral $\mathrm{feO}_{3}$, martite, is only an altered magnetite.

Pyr., etc.-B.B. very difficultly fusible. In O.F. loses its influence on the magnet. With the fluxes reacts like hematite. Soluble in hydrochloric acid.
Diff.-Distinguished from other members of the spinel group, as also from garnet, by its being attracted by the magnet, as well as by its high specific gravity. Also, when massive. by its black streak from hematite and limonite.
Obs.-Magnetite is mostly confined to crystalline rocks, and is most abundant in metamorphic rocks, though found also in grains in eruptive rocks. In the Archæan rocks the beds are of immense extent, and occur under the same conditions as those of hematite. It is an ingredient in most of the massive variety of corundum called emery. The earthy magnetite is found in bogs like bog-iron ore.
Extensive deposits occur at Arendal, Norway; Dannemora and the Täberg in Smaoland; in Lapland. Fahlun in Sweden, and Corsica, afford octahedral crystals.

In N. America, it constitutes vast beds in the Archæan, in the Adirondack region, in Northern N. York ; also in Canada; at Cornwall in Pennsylvania, and at Magnet Cove, Arkansas. Alsá found in Putnam Co. (Tilly Foster Mine), N. Y., etc. In Conn., at Haddam. In Penn., at Chester Co. in mica at Pennsbury. In California, in Sierra Co.; in Plumas Co., and elsewhere. In N. Scotia, Digby Co., Nichol's Mt.
Magnesioferrite (magnoferrite).- $\mathrm{MgFeO}_{4}$. In octahedrons; resembling magnetito. Vesuvius.

## FRANKIINITE.

Isometric. Habit octahedral. Cleavage: octahedral, indistinct. Alsc massive, coarse or fine granular to compact.
$H .=5 \cdot 5-6 \cdot 5$. G. $=5 \cdot 069$. Lustre metallic. Color iron-black. Streak dark reddish-brown. Opaque. Fracture conchoidal. Brittle. Acts slightly on the magnet.

> Comp.- $(\mathrm{Fe}, \mathrm{Zn}, \mathrm{Mn})(\mathrm{Fe}, \mathrm{Mn}) \mathrm{O}_{4}$, or corresponding to the general formula of the spwes group, though varying much in relative amounts of iron, zinc, and manganese. Analysis, Sterling Hill, N. J., ${ }^{4} \mathrm{FeO}_{3} 67 \cdot 42, \mathrm{AlO}_{3} 0 \cdot 65, \mathrm{FeO} 15 \cdot 65, \mathrm{ZnO} 6 \cdot 78, \mathrm{MnO} 9 \cdot 53=100 \cdot 12$, Seyms Q. ratio for R : $\mathrm{m}=1: 1$ nearly. In a crystal from Mine Fill, N. J., Seyms found $4 \cdot 44$ p. c. $\mathrm{MnO}_{3}$.
> The evolution of chlorine in the treatment of the mineral is attributed by v. Kobell to the presence of a little $\mathrm{HnO}_{3}(0.80$ p. c.) as mixture, which Rammelsberg observes may have come from the oxidation of some of the protoxide of manganese.
> Pyr., etc.-B.B. infusible. With borax in O.F. gives a reddish amethystine bead (manganese), and in R.F. this becomes bottle-green (iron). With soda gives a bluish-green manganate, and on charcoal a faint coating of zinc oxide, which is much more marized when a mixture of borax and soda is used. Soluble in hydrochloric acid, with evolution of a small amount of chlorine.
> Diff.-Resembles magnetite, but is only slightly attracted by the magnet; it also react for zinc on charcoal B.B.

Obs.-Occurs in cubic crystals near Eibach in Nassau ; in amorphous masses at Altenberg: near Aix la Chapelle. Abundant at Hamburg, N. J., near the Franklin furnace; also ai Stirling Hill, in the same region.

## CHROMITE.* Chromic Iron. Chromeisenstein, Germ.

Isometric. In octahedrons. Commonly massive; structure fine granular or compact.
$\mathrm{H} .=5 \cdot 5$. G. $=4 \cdot 321-4 \cdot 568$. Lustre submetallic. Streak brown. Color between iron-black and brownish-black. Opaque. Fracture uneven. Brittle. Sometimes magnetic.
Comp. $-\mathrm{Fe}_{\mathrm{CrO}}^{4}$, or $(\mathrm{Fe}, \mathrm{Mg}, \mathrm{Cr})(\mathrm{Al}, \mathrm{Fe}, \mathrm{Cr}) \mathrm{O}_{4} . \quad \mathrm{Fe} \mathrm{CrO}_{4}=$ Iron protoxide 32 , chromium sesquioxide $68=100$. Magnesia is generally present, and in amounts varying from $6-24 \mathrm{p}$. c.

Pyr., etc.-B.B. in O.F. infusible; in R.F. slightly rounded on the edges, and becomes magnetic. With borax and salt of phosphorus gives beads, which, while hot, show only a reaction for iron, but on cooling become chrome-green; the green color is heightened by fusion on charcoal with metallic tin. Not acted upon by acids, but decomposed by fusicn with potassium or sodium bisulphate.

Diff.-Distinguished from magnetite by the reaction for chromic acid with the blowpipe.
Obs.-Occurs in serpentine, forming veins, or in imbedded masses. It assists in giving the variegated color to verde-antique marble. Also occurs in meteorites.

Occurs in Syria; Shetland ; in Norway ; in the Department du Var in France; in Silesia and Bohemia; in the Urals; in New Caledonia. At Baltimore, Md., in the Bare Hills ; at Cooptown. In Pennsylvania, in Chester Co. ; at Wood's Mine, near Tepas, Lancaster Co.. etc. Chester, Mass. In California, in Monterey Co., etc.

This ore affords the chromium oxide, used in painting, etc. The ore employed in England is obtained mostly from Baltimore, Drontheim in Norway, and the Shetland İsles.

Chrompicotite (Petersen).-A maguesian chromite. Color black. New Zealand.

Uraninite* (Pitchblende; Uranpecherz, Germ.). $-\mathrm{U}_{3} \mathrm{O}_{8}\left(\mathrm{UO}_{2}+2 \mathrm{UO}_{8}\right)$. Massive. Black. Saxony, etc.

## CHRYSOBERYL.

Orthorhombic. $\quad I \wedge I=129^{\circ} 38^{\prime}, 0 \wedge 1-\bar{\imath}=129^{\circ} 1^{\prime} ; \dot{c}: \bar{b}: \check{a}=1 \cdot 2285$ : $2 \cdot 1267: 1 . \quad i-\bar{\imath} \wedge 1=136^{\circ} 52^{\prime}, i-\bar{\imath} \wedge$


Norway, Me.


Alexandrite. $2-\Sigma=128^{\circ} 52^{\prime}, i-\check{\imath} \wedge 1-\check{\imath}=120^{\circ} 7^{\prime}$. Plane $i-\bar{\imath}$ vertically striated; and sometimes also $i-\check{\ell}$, and other vertical planes. Cleavage: 1-乞 quite distinct; $i-\check{\imath}$ imperfect ; $i-\bar{\imath}$ more so. Twins: twinning-plane $3-\check{\imath}$, as in f. 477 (see p. 97), made $n \mathrm{p}$ of 6 parts by the crossing of 3 crystals.

$$
H .=8 \cdot 5 . \quad G .=3: \frac{2}{2} \cdot 3 \cdot 84 . \text { Lustre }
$$ vitreous. Color asparagus-green, grass-green, emerald-green, green-ish-white, and yellowish-green, wonetimes raspberry or columbine-red by transmitted light. Streak uncolored. Transparent-translucent. Sometimes a bluish opalescence internally. Fracture conchoidal, uneven.

Var. 1. Ordinary.-Color pale green, being colored by iron. G. $=3.597$, Haddam; 3.734. Brazil; 3.689 , Ural, Rose ; 3.835, Orenburg, Kokscharof. 2. Alexandrite.-Color emerald: green, but columbine-red by transmitted light. G. $=3 \cdot 644$, mean of results, Kokscharof. Supposed to be colored by chrome. Crystals often very large, and in twins, like f. 477, either six-sided or six-rayed.

Comp.-Be $\mathrm{HlO}_{4}=$ Alumina $80 \cdot 2$, glucina $19 \cdot 8=100$. Iron is also often present, though not in the transparent varieties. Isomorphous with chrysolite.
Pyr., etc.-B. B. alone unaltered; with soda, the surface is merely rendered dull. With borax or salt of phosphorus fuses with great difficulty. With cobalt solution, the powdered mineral gives a bluish color. Not acted upon by acids.

Diff.-Distinguished by its extreme hardness, greater than that of topaz; and its infusi. bility; also characterized by its tabular crystallization, in contrast with beryl.
Obs.-In Brazil and also Ceylon; at Marchendorf in Moravia ; in the Ural; in the Mourne Mts., Ireland; at Haddam, Ct. ; at Norway, Me.
When transparent, and of sufficient size, chrysoberyl is cut with facets, and forms a beautiful yellowish-green gem. If opalescent, it is usually cut en cabochon.

## (d) Deutoxides, $\mathrm{RO}_{2}$.

## Rutile Group. Tetragonal.

CASSITERITE. Tin Stone. Zinnstein, Zinnerz, Germ.
Tetragonal. $O \wedge 1-i=146^{\circ} 5^{\prime} ; \dot{c}=0.6724 .1 \wedge 1$, pyr., $=121^{\circ} 40^{\prime}$; $I \wedge 1=133^{\circ} 34^{\prime}$; 1-i $\wedge 1-i$, pyr., $=133^{\circ} 31^{\prime}$. Cleavage: I and $i-i$ hardly distinct. Twins: f. 478, twinning-plane $1-i$; producing often complex forms through the many modifying planes; sometimes repeated parallel to all the eight planes $1-i$; also $f$. 480, a metagenic twin. Often in reniform shapes, structure fibrous divergent; also massive, grauular or impalpable.

H. $=6-7$. G. $=6 \cdot 4-7 \cdot 1$. Lustre adamantine, and crystals usually splendent. Color brown or black; sometimes red, gray, white, or yellow. Streak white, grayish, brownish. Nearly transparent-opaque. Fracture sribconchoidal, ụneven. Brittle.

[^36]although very compact, with the color brownish, of mixed shades, looking somewhat like dry wood in its colors. G. of one variety 6.514 . Stream tin is nothing but the ore in the state of sand, as it occurs along the beds of streams or in the gravel of the adjoining region. It has been derived from tin veins or rocks, through the wear and decomposition of the rocks and transportation by water.

Comp.- $\mathrm{SnO}_{2}=$ Tin 78.6, oxygen $21 \cdot 4=100$.
Pyr., etc.-B.B. alone unaltered. On charcoal with soda reduced to metallic tin, and gives a white coating. With the fluxes sometimes gives reactions for iron and manganese. and more rarely for tantalic oxide. Only slightly acted upon by acids.

Diff.--Distinguished by its high specific gravity, its infusibility, and by its yielding metallio tin B.B. from some varieties of garnet. sphalerite, and black tourmaline, to which it has mome resemblance. Specific gravity ( 6.5 ) higher than that of rutile (4).

Obs.-Tin ore is met with in veins traversing granite, gneiss, mica schist, chlorite or clay schist, and porphyry. Occurs in Cornwall; in Devonshire; in Bohemia and Saxony ; at Limoges ; also in Galicia; Greenland ; Sweden, at Finbo; Finland, at Pitkaranta. In the E. Indies ; in Victoria and New South Wales; in large quantities in Queensland. In Bolivia, S. A. ; in Mexico.

In the United States, rare : in Maine, at Paris ; in N. Hamp., at Lyme; in California, in San Bernardino Co. ; in ldaho, near Boonville.

## RUTILE.*

Tetragonal. $O \wedge 1-i=147^{\circ} 12 \frac{1}{2}^{\prime}, \dot{c}=0.6442 . \quad 1 \wedge 1$, pyr., $=123^{\circ} 7 \frac{1}{2}^{\prime}$, $I \wedge 1=132^{\circ} 20^{\prime}$. Cleavage: $I$ and $i-i$, distinct; 1, in traces. Vertical planes usually striated. Crystals often acicular. Twins: (1) twinning-plane 1-i (see p. 94). (2) $3-i$, making a wedge-shaped crystal consisting of two individuals. (3) $1-i$ and $3-i$ in the same crystal (fr. Magnet Cove, Hessenberg). Occasionally compact, massive.

$\mathrm{H} .=6-6 \cdot 5$. G. $=4 \cdot 18-4 \cdot 25$. Lustre metallic-adamantine. Cr,lor ir.d. dish-brown, passing into red ; sometimes yellowish, bluish, , whet, black ; rarely grass-green. Streak pale brown. Subtransparent-opaque. lracture subconchoidal, uneven. Brittle.

[^37]Diff. Characterized by its peculiar sub-adamantine lustre, and brownish-red color. Differn Kom $\uparrow$ armaline, vesuvianite, augite in being entirely unaltered when heated alone B.B. Speci $\%$, gravity about 4, cassiterite 6.5 .

O's.s.- Rutile occurs in granite, gneiss, mica slate, and syenitic rocks, and sometimes in grap car limestone and dolomite. It is generally found in imbedded crystals, often in masses of quartz or feldspar, and frequently in acicular crystals penetrating quartz. Very commonly implanted in regular position upon crystals of hematite, as from Cavradi in the Tavetschthal. Occurs in Norway; Finland ; Saualpe, Carinthia; in the Urals ; in the Tyrol ; at St. Gothard near Freiberg ; at Ohlapian in Transylvania.

In Mrine, at Warren. In Vermont, at Waterbury and elsewhere. In Mass., at Barre ; Shelburne; Sheffield. In Conn., at Lane's mine, Monroe. In N. York, in Orange Co.; Edenville; Warwick. In Penn., Chester Co. In N. Car., at Crowder's Mountain. In Georgia, in Habersham Co. ; in Lincoln Co., at Graves' Mountain. In Arkansas, at Magnet Cove.

Titanium oxide is employed for a yellow color in painting porcelain, and also for giving tha requisite tint to artificial teeth.

## OCTAHEDRITE.* Anatase.

Tetragonal. $O \wedge 1-i=119^{\circ} 22^{\prime} ; \dot{c}=1 \cdot 77771$. Cominonly octahedras or tabular. $1 \wedge 1$, pyr., $=$ $\varsigma 7^{\circ} 51^{\prime} . \quad I \wedge 1=158^{\circ} 18^{\prime}$. Cleavage: 1 and $O$, perfect.

$$
\mathrm{H} .=5 \cdot 5-6 . \quad \mathrm{G} .=3 \cdot 82-
$$

3.85 ; sometimes $4 \cdot 11-4 \cdot 16$ after heating. Lustre metallic-adamantine. Col-


Binnenthal. or various shades of brown, passing into indigo-blue, and black; greenish-yellow by transmitted light. Streak uncolored. Fracture subconchoidal. Brittle.

Comp.-Like rutile and brookite, pure titanic oxide. Pyr., etc.-Same as for rutile.


Obs.-Abundant at Bourg d'Oisans, in Dauphiny ; also in the Binnenthal (including here Kenngott's wiserine, f. 484, as shown by Klein, Jahrb. Min., 1875, 337); at Pfitsch Joch, Tyrol ; near Hof in the Fichtelgebirge; Norway; the Urals; in Devonshire, near Tavistock; at Tremadoc, in North Wales; in Cornwall; in Brazil in quartz. In the U. States, at Smithfield, R. I.

HaUSMANNITE. $-\mathrm{Mn}_{3} \mathrm{O}_{4}=2 \mathrm{MnO}, \mathrm{MnO}_{2}$. Tetragonal, $0 \wedge 1-i=130^{\circ} 25^{\prime}$. Color brownishblack. Thuringia; Harz, etc.

Braunite. $-2\left(2 \mathrm{MnO}, \mathrm{MnO}_{2}\right)+\mathrm{MnO}_{2}, \mathrm{SiO}_{2}$. Tetragonal, $0 \wedge 1-i=135^{\circ} 26^{\prime}$. Color dark brownish-black. Thuringia; Norway, etc.

Minium (Mennige, Germ.). $-\mathrm{Pb}_{3} \mathrm{O}_{4}=\mathrm{PbO}_{2}+2 \mathrm{PbO}$. Badenweiler; Wythe Co., Va., etc.

## BROOKITE.*

Orthorhombic (\%). $I \wedge I=99^{\circ} 50^{\prime}\left(-100^{\circ} 50^{\prime}\right): \quad 0 \wedge 1-i=131^{\circ} 42^{\prime}$; $d: \bar{b}: \check{a}=1 \cdot 1620: 1 \cdot 1883: 1$. Cleavage: $I$, indistinct; $O$, still more so. $\mathrm{H} .=5 \cdot 5-6$. G. $=4 \cdot 12-4 \cdot 23$, brookite $; 4 \cdot 03-4 \cdot 085$, arkansite. Hair-brown, vellowish, or reddish, with metallic adamantine lustre, and translucent
(brookite); also ircn-black, opaque, and submetallic (arkaneite). Streals uncolored-grayish, yellowish. Brittle.


Comp-Pure titanic oxide, $\mathrm{TiO}_{2}$, like rutile and octahedrite.
Pyr., etc.-Same as for rutile.
Obs.-Brookite occurs at Bourg d'Oisans in Dauphiny ; at St. Gothard; in the Urals, near Miask; in thick black crystals (arkansite f. 486) at Magnet Cove, Arkansas, sometimes altered to rutile by paramorihism; at Ellenville, Ulster Co., N. Y. ; at Paris, Maine.

Schrauf has announced (Atlas Min., Reich. IV.) that he has found brookite to be monoclinis (and isomorphous with wolframite). He distinguishes three types having different axial relations. The measurements of v. Rath, however, seem to show that in part it must be orthorhombic.

Eumanite.-From Chesterfield, Mass., may be identical with brookite.

Orthorhombic. $I \wedge I=93^{\circ} 40^{\prime}, O \wedge 1-\bar{\imath}=142^{\circ} 11^{\prime} ; \dot{c}: \bar{b}: \breve{a}=0.776$ : $1 \cdot 066: 1$. Cleavage $I$ and $i-\check{\imath}$. Also columnar, often
 divergent; also granular massive, and frequently in reniform coats. Often soils.
$\mathrm{H}_{.}=2-2 \cdot 5$. G. $=4 \cdot 82$. Turner. Lustre metallic. Color iron-black, dark steel-gray, sometimes bluish. Streak black or bluish-black, sumetimes submetallic. Opaque. Rather brittle.

Comp. $-\mathrm{MnO}_{2}=$ Manganese 63:2, oxygen $36 \cdot 8=100$.
Pyr., etc.-B.B. alone infusible; on charcoal loses oxygen. A manganese reaction with borax. Affora's chlorine with hydrochloric acid.

Diff.-Harduess less than that of psilomelane. Differs from iron ores in its reaction for manganese B.B. Easily distinguished from psilomelane by its inferior hardness, and usually by being crystalline.

Obs.-Occurs extensively at Elgersberg near Ilmenau in Thuringia; at Vorderehrensdorf in Moravia; at Platten in Bohemia, and elsewhere. Occurs in the United States in Vermont, at Brandon, etc. ; at Conway, Mass. ; at Winchester, N. H. ; at Salisbury and Kent, Conn. In California, on Red island, bay of San Francisco. In New Brunswick, near Bathurst. In Nova Scotia, at Walton; Pictou, etc.

Pyrolusite and manganite are the most important of the ores of manganese. Pyrolusite parts with its oxygen at a red heat, and is extensively employed for discharging the brown and green tints of glass. It hence received its name from $\pi \stackrel{v}{v} \rho$, five, and $\lambda \dot{v} \omega$, to woash.

Crednerite. $--\mathrm{Cu}_{3} \mathrm{Afn}_{2} \mathrm{O}_{9}$, or $3 \mathrm{CuO}+2 \mathrm{AnO}_{3}$. Foliated. Color black. Thuringia.

## B. HYDROUS OXIDES.

## TURGITE.

Compact fibrous and divergent, to massive ; often botryoidal and stalactitic like limonite. Also earthy, as red ochre.
H. $=5-6$. G. $=3 \cdot 56-3 \cdot 74$, from Ural ; 4•29-4•49, fr. Hof; 4.681, fr. Horhausen; $4 \cdot 14$, fr. Salisbury. Lustre submetallic and somewhat satinlike in the direction of the fibrons structure; also dull earthy. Color reddish-black, to dark red; bright-red when earthy; botryoidal surface often lustrons, like much limonite. Opaque.

Comp. $-\mathrm{H}_{2} \mathrm{Fe}_{2} \mathrm{O}_{7}=$ Iron sesquioxide $94 \cdot 7$, water $5 \cdot 3=100$.
Pyr., etc.-Heated in a closed tube, flies to pieces in a remarkable manner ; yields water. Otherwise like hematite.

Diff.-Distinguished from hematite and-limonite by its superior hardness, the color of its streak, and B.B. its decrepitation.

Obs.-A very common ore of iron. Occurs at the Turginsk copper mine near Bosgolovsk, in the Ural ; near Hof in Bavaria, and Siegen in Prussia; at Horhausen. In the U. S. it occurs at Salisbury, Ct.

## DIASPORE.

Orthorhombic. $\quad I \wedge I=93^{\circ} 423^{\prime}, \quad O \wedge 1-\bar{\imath}=147^{\circ} \quad 12 \frac{11^{\prime}}{} ; \dot{c}: \bar{b}: a ̆=$ $0.64425: 1.067: 1 . \quad i-\imath \wedge 1-\imath=121^{\circ} 7 \frac{1}{2}, \quad i-\imath \wedge 1-\overline{2}=104^{\circ}$ $14 \frac{1^{\prime}}{}{ }^{\prime}, i-\check{ } \wedge \wedge 1=116^{\circ} 54 \frac{1_{2}^{\prime}}{}{ }^{\prime}$. Crystals usually thin, flattened parallel to $i-\imath$; sometimes acicular; commonly implanted. Cleavage: $i-\check{\imath}$ eminent; $i-\overline{2}$ less perfect. Occurs foliated massive and in thin scales; sometimes stalactitic.
$\mathrm{H} .=6 \cdot 5-7 . \quad \mathrm{G} \cdot=3 \cdot 3-3 \cdot 5$. Lustre brilliant and pearly on cleavage-face; elsewhere vitreous. Color whitish, grayishwhite, greenish-gray, hair-brown, yellowish, to colorless; sometimes violet-blue in one direction, reddish plumb-blue in another, and pale asparagus-green in a third. When thin, translucent-subtranslucent. Very brittle.


Comp. $-\mathrm{H}_{2} \mathrm{AlO}_{4}=$ Alumina $85 \cdot 1$, water $14 \cdot 9=100$; a littJe phosphorus pentoxide is often present.

Pyr., etc.-In the closed tube decrepitates strongly, separating into pearly white scales. and at a high temperature yields water. The variety from Schemnitz does not decrepitate. Infusible; with cobalt solution gives a deep blue color. Some varieties react for iron with the fluxes. Not attacked by acids, but after ignition becomes soluble in sulphuric acid.

Diff.-Distinguished (B.B.) by its decrepitation and yielding water ; as also by the reaction for alumina with cobalt solution. Resembles some varieties of hornblende, but is harder.
Obs.-Commonly found with corundum or emery. Occurs in the Ural; at Scbemnitz; at Broldbo near Fahlun; in Switzerland ; in Asia Minor, and the Grecian islands; in Chester Co., Pa. ; at the emery mines of Chester, Mass. ; N. Carolina.

Dicspore was named by Haüy from d $\delta a \sigma \pi \varepsilon i \rho \omega$, to scatter, alluding to the zsual decrepitation before the blowpipe,

## GÖTHITE.

Orthorhnmbic. $I \wedge I=94^{\circ} 52^{\prime}$ (B. \& M.) ; $O \wedge 1-\bar{\imath}=146^{\circ} 33^{\prime} ; \dot{c}: \vec{b}: d$ $=0 \cdot 66: 1 \cdot 089: 1$. In prisms longitudinally striated, and often flattened into scales or tables parallel to the shorter diagonal. Cleavage: brachydiagonal, very perfect. Also fibrons; foliated or in scales; massive; reniform; stalactitic.
$\mathrm{H} .=5-5 \cdot 5 . \quad \mathrm{G} .=4 \cdot 0-4 \cdot 4$. Lustre imperfect adamantine. Color yellowish, reddish, and blackish brown. Often bloodred by transmitted light. Streak brownish-yellow-ochreyellow.

Var.-1. In thin scale-like or tabular crystals, usually attached by one edge. 2. In acicular or capillary (not flexible) crystals, or slender prisms, often radiately grouped : the Needle-Ironstone (Nadeleisenstein). It passes into (b) a variety with a velvety surface: the Przibramite (Sammetblende) of Przibram is of this kind. Other varieties are columnar or fibrous, scaly-fibrous. or feathery columnar; compact massive, with a flat conchoidal fracture; and sometimes reniform or stalactitic.

Comp. $-\mathrm{H}_{2} \mathrm{FeO}_{4}=\mathrm{H}_{6} \mathrm{FeO}_{6}+2 \mathrm{FeO}_{3}=$ Iron sesquioxide $89 \cdot 9$, water $10 \cdot 1=100$.
Pyr., etc.-In the closed tube gives off water and is converted into red iron sesquioxide. With the fluxes like hematite; most varieties give a manganese reaction, and some treated in the forceps in O.F., after moistening in sulphuric acid, impart a bluish-green color to the flame (phosphoric acid). Soluble in hydrochloric acid.

Obs.-Found with the other iron oxides, especially hematite or limonite. Occurs at Eiser feld; in Nassau; at Zwickau in Saxony; in Cornwall ; in Somersetshire, at the Providence iron mines. In the U. States, near Marquette, L. Superior ; in Penn., near Easton; in California, at Burns Creek, Mariposa Co.

Named Göthite after the poet-philosopher Göthe; and Pyrrhosiderite from $\pi v \rho \dot{\rho} \rho \rho$, fire-red, and oidnpos, iron.

## manganite.

Orthorhombic. $I \wedge I=99^{\circ} 40^{\prime}, O \wedge 1-\bar{\imath}=147^{\circ} 9 \frac{1}{2}^{\prime} ; \dot{c}: \bar{b}: \breve{a}=0.6455$ : $1 \cdot 185$ : 1. Twins: twinning-plane $1-\check{\iota}$ (f. 296, p. 96). Cleavage: $i-乞$ very perfect, I perfect. Crystals longitudinally striated, and often grouped in bundles. Also columnar; seldom granular; stalactitic.
$\mathrm{H}=4$. G. $=4 \cdot 2-4 \cdot 4$. Lustre submetallic. Color dark steel-gray-ironblack. Streak reddish-brown, sometimes nearly black. Opaque; minute splinters sometimes brown by transmitted light. Fracture uneven.

Comp. $-\mathrm{H}_{2} \mathrm{MnnO}_{4}=\mathrm{H}_{6} \mathrm{MnO}_{6}+2 \mathrm{HnO}_{3}=\mathrm{Manganese}^{2}$ sesquioxide $89 \cdot 8$ ( $=\mathrm{Mn} 62 \cdot 5$, $0 \quad 27 \cdot 3$ ), water $10 \%=100$.
Pyr., etc.-In the closed tube yields water ; otherwise like brannite.
Obs.-Occurs in veins traversing porphyry, at Ilefeld in the Harz; in Thuringia; Undenaes in Sweden; Christiansand in Norway; Cornwall, at various places; also in Cumberland, Devonshire, etc. In Nova Scotia, at Cheverie, etc. In New Brunswick, at Shepody mountain, Albert Co., etc.

LIMONITE. Brown Hematite. Brauneisenstein, Germ.
Usually in stalactitic and botryoidal or mammillary forms, having a fibrous or subfibrous structure; also concretionary, massive; and occasionally earthy.
H. $=5-5 \cdot 5 . \quad$ G. $=3 \cdot 6-4$. Lustre silky, often submetallic ; sometimes dull and earthy. Color of surface of fracture various shades of brown, commonly dark, and none bright; sometimes with a nearly black varnish-like exterior; when earthy, brownish-yellow, ochre-yellow. Streak yellowishbrown.

Var.- (1) Compact. Submetallic to silky in lustre; often stalactitic, botryoidal, etc. (2) Ochreous or earthy, brownish-yellow to ochre-yellow, often impure from the presence of clay, sand, etc. (3) Bog ore. The ore from marshy places, generally loose or porous in texture, often petrifying leaves, wood, nuts. etc. (4) Brown clay-ironstone, in compact masses, often in concretionary nodules, having a brownish-yellow streak, and thus distinguishable from the clay-ironstone of the species hematite and siderite; it is sometimes (a) pisolitic, or an aggregation of concretions of the size of small peas (Bohnerz, Germ.); or (b) oolitic.

Comp. $-\mathrm{H}_{6} \mathrm{Fe}_{2} \mathrm{O}_{9}=\mathrm{H}_{6} \mathrm{Fe} \mathrm{O}_{6}+\mathrm{FeO}_{3}=$ Iron sesquioxide $80{ }^{\circ} 6$, water $14 \cdot 4=100$. In the bog ores and ochres, sand, clay, phosphates, manganese oxides, and humic or other acids of organio origin are very common impurities.
Pyr., etc.-Like göthite. Some varieties give a skeleton of silica when fused with salt of phosphorus, and leave a siliceous residue when attacked by acids.
Diff.-Distinguished from hematite by its yellowish streak, inferior hardness, and its reaction for water. Does not decrepitate, B.B., like turgite.

Obs.-Limonite occurs in secondary or more recent deposits, in beds associated at times with barite, siderite, calcite, aragonite, and quartz ; and often with ores of manganese; alsu as a modern marsh deposit. It is in all cases a result of the alteration of other ores, through exposure to moisture, air, and carbonic or organic acids; and is derived largely from the change of pyrite, siderite, magnetite, and various mineral species (such as mica, augite, hornblende, etc.!, which contain iron in the protoxide state.
Abundant in the United States. Extensive beds exist at Salisbury and Kent, Conn., also in the neighboring towns of N. Y., and in a similar situation north; at Richmend and Lenox, Mass. ; in Vermont, at Bennington, etc.
Limonite is one of the most important ores of iron. The pig iron, from the purer varieties, obtained by smelting with charcoal, is of superior quality. That yielded by bog ore is what is termed cold short, owing to the phosphorus present, and cannot therefore be employed in the manufacture of wire, or even of sheet iron, but is valuable for casting. The hard and compact nodular varieties are employed in polishing metallic buttons, etc.
Melanosiderite.-Near limonite, but containing 7•39 p. c. $\mathrm{SiO}_{2}$, perhaps as an impurity. Cooke regards it as a very basic silicate of iron. G. $=3 \times 39$. Westchester, Penn.
Xanthosiderite. - $\mathrm{H}_{4} \mathrm{FeO}_{5}=\mathrm{FeO}_{8} 81 \cdot 6, \mathrm{H}_{2} \mathrm{O} \quad 18 \cdot 4=100$; or $\mathrm{H}_{6} \mathrm{FeO}$ 。(Ramm.). In fine needles. Color yellow, brown. Ilmenau; the Harz.

BEAUXITE.-Occurs in concretionary grains. Color whitish to brown. Composition doubtful, perhaps $\mathrm{Al}(\mathrm{Fe}) \mathrm{O}_{3}+2 \mathrm{aq}$. Beaux, near Arles, France; near Lake Wochein, Styria (wocheinite) ; French Guiana.

## BRUCITE.*

Rhombohedral. $\quad R \wedge R=82^{\circ} 22 \frac{1}{2}^{\prime}, O \wedge R=119^{\circ} 39 \frac{1_{2}^{\prime}}{} ; \quad \dot{c}=1.52078$ (Hessenberg). Crystals often broad tabular. Cleavage: basal, eminent

folia easily separable, nearly as in gypsum. Usually foliated massive. Also fibrous, fibres separable and elastic.
H. $=2 \cdot 5$. G. $=2 \cdot 35-2 \cdot 44$. Lustre pearly on a cleavage-face, elsewhere between waxy and vitreous; the fibrous silky. Color white, inclining to gray, blue, or green. Streak white. Translucent-subtranslucent. Sectile. Thin laminæ flexible.

Comp. $-\mathrm{H}_{2} \mathrm{MgO}_{2}=$ Magnesia 69, water $31=100$.
Var.-1. Foliated. 2. Fibrous; called nemalite, containing 4 or 5 p. c. of FeO .
Pyr., etc.-In the closed tube gives off water, becoming opaque and friable, sometimes turning gray to brown. B.B. infusible, glows with a bright light, and the ignited mineral reacts alkaline to test paper. With cobalt solution gives the violet-red color of magnesia. The pure mineral is soluble in acids without effervescence.

Diff.-Distinguished by its infusibility. Differs from talc in its solubility in acids.
Obs.-Brucite accompanies other magnesian minerals in serpentine, and has also been found in limestone. Occurs at Swinaness in Unst, Shetland Isles; in the Urals; at Goujot in France ; near Filipstadt in Wermland. It occurs at Hoboken, N. J. ; in Richmond Co., N. Y. ; at Brewster, N. Y. ; at Texas, Pa. The fibrous variety (nemalite) occurs at Hoboken, and at Xettes in the Vosges.

## GIBBSITE.

Monoclinic (DesCl.). In small hexagonal crystals with replaced lateral edges. Planes vertically striated. Cleavage : basal or $O$ eminent. Occasionally in lamello-radiate spheroidal concretions. Usually stalactitic, or small mammillary and incrusting, with smooth surface, and often a faint fibrous st ructure within.
$\mathrm{H} .=2 \cdot 5-3 \cdot 5 . \quad \mathrm{G} .=2 \cdot 3-2 \cdot 4 . \quad$ Color white, grayish, greenish, or reddishwhite; also reddish-yellow when impure. Lustre of $O$ pearly; of other faces vitreous; of surface of stalactites faint. Translucent; sometimes transparent in crystals. A strong argillaceous odor when breathed on. Tough.

Var.-1. In crystals : the original hydrary ${ }^{\text {Titite }}$ 2. Stalactitic ; gibbsite.
Comp. $-\mathrm{H}_{6}-\mathrm{AlO}_{6}=$ Alumina $65^{\circ} 5$, water $34.5=100$.
Pyr., etc.-In the closed tube becomes white and opaque. and yields water. B.B. infusible, whitens, and does not impart a green color to the flame. With cobalt solution gives a deepblue color. Soluble in concentrated sulphuric acid.
Diff.--Resembles chalcedony in appearance, but is softer.
Obs.-The crystallized gibbsite occurs near Slatoust in the Ural; at Gumuchdagh. Asia Minor ; on corundum at Unionville, Pa.; in Brazil. The stalactitic occurs at Richmond, Mass.; at the Clove mine, Duchess Co., N. Y.; in Orange Co., N. Y.

Rose's hydrargillite (Urals, 1839) is identical with gibbsite (Torrey, 1822), and must receive this name. An uncertain mineral from Richmond afforded Hermann 38 p. c. of phosphorio acid, but a phosphate, if it really occurs there, is not gibbsite.

Prrocirmoite. $-\mathrm{H}_{2} \mathrm{MnO}_{2}=$ Manganese protoxide $79 \cdot 8$, water $20 \cdot 2=100$. Foliated. Colur white. Mine of Paisberg, Filipstadt, Sweden.

Hydrotalcite from Snarum, Norway, and Völknerite from the Urals, contain alumina, magnesia, and water with more or less carbon dioxide. Probably mixtures, containing brucite, gibbsite, etc. Hovahite from Oxbow and Rossie, N. Y., is a similar mineral derived from the alteration of spinel. Namaqualite (Church). A related mineral ; from Namaqualand, So. Africa.

## PSILOMELANE.*

Massive and botryoidal. Reniform. Stalactitic.
$\mathrm{H} .=5-6$. G. $=3 \cdot 7-47$. Lustre submetallic. Streak brownish-black, shining. Color iron-black, passing into dark steel-gray. Opaque.

Comp.-Somewhat doubtful. Contains manganese oxide, with varying amounts of baryta, and potash (lithia), and also water. General formula, according to Rammelsberg, $\mathrm{R}_{5} \mathrm{O}_{9}=\mathrm{RO}$ $+4 \mathrm{MnO}_{2}$, where R is $\mathrm{Ka}_{2}, \mathrm{Ba}$ or Mn . Analyses:

|  | O | MnO | BaO | $\mathrm{K}_{2} \mathrm{O}$ | $\mathrm{H}_{2} \mathrm{O}$ |  |  |
| :--- | :---: | :---: | :---: | :---: | :---: | :--- | :--- | :--- | :--- |
| 1. Thüringen | $11 \cdot 43$ | $65 \cdot 76$ | $16 \cdot 59$ | - | $5 \cdot 25$ | $\mathrm{CuO} 0.59, \mathrm{CoO} 0.79, \mathrm{CaO}$$0.51=100 \cdot 7 \%$ <br> Olschewsky. |  |
| 2. limenau | 15.82 | $77 \cdot 23$ | 0.12 | $5 \cdot 20$ | - | $\mathrm{CaO} 0.91, \mathrm{CuO} \quad 0.40=99 \cdot 77$ Clausbruch. |  |

Pyr., etc.-In the closed tube most varieties yield water, and all lose oxygen on ignition; with the fluxes reacts for manganese. Soluble in hydrochloric acid, with evolution of chlorine.

Obs.-This is a common ore of manganese. It occurs in Devonshire and Cornwall; at Ilefeld in the Harz; also at Johanngeorgeustadt; Schneeberg; Ilmenau; Siegen, etc. It forms mammillary masses at Chittenden, Irasburg, and Brandon, Vt.

## WAD.

The manganese ores here included occur in amorphons and reniform masses, either earthy or compact, and sometimes incrusting or as stains. They are mixtures of different oxides, and cannot be considered chemical compounds or distinct inineral species.
$\mathrm{H} .=0 \cdot 5-6 . \quad \mathrm{G} .=3-4 \cdot 26$; often loosely aggregated, and feeling very light to the hands. Color dull black, bluish or brownish-black.

Comp., Var.-Perhaps $\mathrm{H}_{2} \mathrm{Mn}_{2} \mathrm{O}_{5}=2 \mathrm{MnO}_{2}+\mathrm{aq}$ (Rammelsberg), but in all cases mixed with other ingredients.
Varieties: (A) Manganesian ; (B) Cobaltiferous; (C) Cupriferous.
A. Bog Manganese. - Consists mainly of manganese dioxide and water, with some iron sesquioxide, and often silica, alumina, baryta.
B. Asbolite, or Earthy Cobalt, is wad containing cobalt oxide, which sometimes amounts to 32 p. c. Lithiophorite, heterogenite, and rabdionite belong near here.
C. Lampadite, or Cupreous Manganese. A wad containing 4 to 18 p . c. of copper oxide, and often cobalt oxide also. It graduates into black copper (Melaconite). G. $=3 \cdot 1-3 \cdot 2$.
Pyr., etc.-Wad reacts like psilomelane. Earthy cobalt gives a blue bead with salt of phosphorus, and when heated in R.F. on charcoal with tin, some specimens yield a red opaque bead (copper). ('upreous manganese gives similar reactions, and three varieties give a strong manganese reaction with soda, and evolve chlorine when treated with hydrochloric acid.

Obs.-The above ores are results of the decomposition of other ores-partly of oxides, and partly of manganesian carbonates. Wad or bog manganese is abundant in the counties of Columbia and Dutchess, N. Y. There are large deposits of bog manganese at Blue Hill Bay, Dover, and other places in Maine.
Earthy cobalt occurs at Riechelsdorf in Hesse; Saalfeld in Thuringia; at Nertschinsk in Siberia; at Alderly Edge in Cheshire.

Cifalcophanite. -Rhombohedral. In druses of minute tabular crystals; also in stalactitic aggregates. H. $=2 \%$. G. $=3 \cdot 907$. Lustre metallic. Color bluish-black. Analysis gave $\mathrm{MnO}_{2} 59.94, \mathrm{MnO} 6 \cdot 58, \mathrm{ZnO} 21 \cdot 70, \mathrm{FeO}_{3} 0.25, \mathrm{H}_{2} \mathrm{O} 11.58=100.05$. Composition $2 \mathrm{MnO}_{2}+$ $(\mathrm{Mn}, \mathrm{Zn}) \mathrm{O}+2 \mathrm{aq}$. If half the water were basic, the formula might be written $2 \mathrm{RMnO}_{3}+\mathrm{aq}$, where $\mathrm{R}=\mathrm{Mn}, \mathrm{Zn}$ and $\mathrm{H}_{2}$ 。 B.B. becomes of a copper color, hence the name ( $\chi \alpha \lambda \varkappa o ́ s$, brass, bronze, and фaiv $\omega$, to appear). Stirling Hill, N. J. (Moore.)

## 2. OXIDES of Elements of the Arsentio and Sulphur Grouprs, Series I]

## VALENTINITE. Weisspiesglaserz, Germ.

Orthorhombic. $I \wedge I=136^{\circ} 58^{\prime} ; O \wedge 1-\bar{\imath}=105^{\circ} 35^{\prime} ; \dot{c}: \bar{b}: \check{a}=3 \cdot 5968$ :
 $2 \cdot 5365: 1$. Often in rectangular plates with the lateral edges bevelled, and in acicular rhombic prisms. Cleavage: $I$, highly perfect, easily obtained. Also massive; structure lanellar, columnar, grannlar.
$\mathrm{H} .=2 \cdot 5-3$. G. $=5 \cdot 566$, crystals from Bräunsdorf. Lustre adamantine, $i-乞$ often pearly ; shining. Curior snow-white, occasionally peach-blossoin red, and ash-gray to brownish. Streak white. Translucent-subtrans. parent.

Comp.- $\mathrm{Sb}_{2} \mathrm{O}_{3}=0 \mathrm{xyg} \in \mathrm{n} 16 \cdot 44$, antimony $83 \cdot 56=100$.
Ob --Found at Przibram in Bohemia; at Felsobanya in Hungary; Bräunsdorf in Saxony Also at South Ham, Canada East.
Senarmontite.*-Same composition as the above, but crystallizes in isometric octahedrons. G. $=5 \cdot 2-5.3$. Perneck, Hungary ; Cornwall ; Haraclas in Algeria; S. Ham, Canada.

Claudetite; Arsenolite. - Both $\mathrm{As}_{2} \mathrm{O}_{3}$. The former is orthorhombic, the latter isometric. They thus correspond to the two forms of $\mathrm{Sb}_{2} \mathrm{O}_{3}$ (see above). Claudetite ( $\mathrm{G} .=3 \cdot 85$ ) occurs in thin plates at the San Domingo mines, Portugal. Arsenolite ( $\mathrm{G} .=3 \cdot 698$ ) occurs usually in capillary crystals, also stalactitic ; earthy. Andreasberg; Joachimsthal ; Cornwall; Ophir mine, Nevada; California.

Bismite (Wismuthocker, Germ ).- $\mathrm{Bi}_{2} \mathrm{O}_{3}$. Occurs massive, earthy. Schneeberg; Joachims thal; Cornwall. Karelinite.-3BiO+BiS. Massive. Color lead-gray. G. $=6 \cdot 60$. Savodinsk mine in the Altai.
Molybdite (Molybdänocker, Germ.).-Composition $\mathrm{MoO}_{3}$. In radiated crystallizations; as an incrustation, etc. Occurs with molybdenite. At Westmoreland, New Hampshire; Chester, Penn.; Virginia City, Nevada. Ilsemannite, near the above. Bleiberg, Carinthia.

Tungstite.- $\mathrm{WO}_{3}$. Pulverulent and earthy. Cornwall; Monroe, Ct. Meymacite (Carnot).-A hydrated tungstite. Meymac, Corrèze.

Kermesite (Antimonblende, Germ.). Composition $\mathrm{Sb}_{2} \mathrm{~S}_{2} \mathrm{O}=2 \mathrm{Sb}_{2} \mathrm{~S}_{3}+\mathrm{Sb}_{2} \mathrm{O}_{3}$. In capillary crystals. Color cherry-red. Bräunsdorf, Saxony; Allemont; South Ham, Canada East.

Cervantite. - $\mathrm{SbO}_{2}=\mathrm{Sb}_{2} \mathrm{O}_{3}+\mathrm{Sb}_{2} \mathrm{O}_{5}$. Color yellow. Results from alteration of stibnite. Spain; Tuscany; Hungary, etc. ; South Ham, Canada.

## 3. OXIDES of the Carbon-silicon Grotr, Series II.

Xeuartz.*
Rhombohedral, and for the most part hemihedral to the rhombohedron (or tetartohedral to the hexagonal prism). $R \wedge R=94^{\circ} 15^{\prime}, O \wedge R=128^{\circ}$ $13^{\prime} ; \dot{c}=1.0999$. $i \wedge 2-2=142^{\circ} 2^{\prime}, R \wedge-1$, ov. $i,=103^{\circ} 34^{\prime}, R \wedge-1$, adj. $=133^{\circ} 44^{\prime}, R \wedge i$, ov. $2-2,=113^{\circ} 8^{\prime}$. Cleavage: $R,-1$, and $i$ very indistinct: sometimes effected by plunging a heated crystal in cold water. Crystals sometimes very short, but general habit prismatic; the crystals
much elongated, sometimes fine acicular; usually implanted by one extremity of the prism. Prismatic faces icommonly striated horizontally, and thus distinguishable, in distorted crystals, from the pyranidal. Crystals often grouped by juxtaposition, not proper twins. Frequently in radiated masses with a surface of prramids, or in druses having a surface of pyramids or short crystals. Twins: twiming-plane, (1), the basal plane $O$ (f. 506); very generally penetration-tiwns, as illustrated in f. 265 , p. 89 . (2) The pyramid $1-2$, trimcating the edge between $+l 2$ and $-l i$, divergence of axes $84^{\circ} 33^{\prime}$. Other methods of twinning rare, parallel to $i$, to $R$, to

$\frac{1}{2} R$, etc. (Jenzsch). Also in pseudo-trillings on calcite, with 2-2 as tha approximate twiming-plane (see f. 336, p. 101).

Massive; coarse or fine granular to flint-like or crypto-crystalline Sometimes mammillary, stalactitic, and in concretionary forms.

H. $=$ 7. G. $=2 \cdot 5-2 \cdot 8 ; 2 \cdot 6413-2 \cdot 6541$ (Bendant). Lustre vitreous, some times inclining to resinous; splendent-nearly dull. Colorless when pure: offen various shades of yellow, red, brown, green, blne, black. Streak white, of pure varieties; if impure, often the same as the color, but much paler. Transparent-opaque. Fracture perfect conchoidal-subconchoidal. Tough-brittle-friable. Pularization circular, see pp. 142-144.

Comp.-Pure silica, or $\mathrm{SiO}_{2}=$ Oxygen 53.33 , silicon $46 \cdot 67=100$. In massive varieties ofven nuixed with a little opal-silica. Impure varieties contain iron sesquioxide, calcium carbonate, clay, sand, and various minerals.

Var.-1 Crystallized (phenocrystalline), vitreous in lustre. 2. Flint-like, massive, or cryptocrystalline. The first division includes all ordinary vitreous quartz, whether having crystalline facesor not. The varieties under the second are in general acted upon somewhat more by attrition, and by chemical agents, as fluohydric acid, than those of the first. In all kinds made up of layers, as agate, successive layers are unequally eroded.

## A. Phenocrystalline or Vitreous Varieties.

1. Ordinary Crystallized; Rock Crystal. Culozless quartz, or nearly so, whether in distinct crystals or not.
2. Asteriuted; Star quartz (Sternquartz, Germ.). Containing within the crystal whitish or colored radiations along the diametral planes.
3. Amethystine; Amethyst. Clear purple, or bluish-violet. The color is supposed to be due to manganese.
4. Rose. Rose-red or pink, but becoming paler on exposure. Common massive, and then usually much cracked. Lustre sometimes a little greasy. Fuchs states that the color is due to titanic oxide. It may come in part from manganese.
5. Yelloro; False Topaz. Yellow and pellucid, or nearly so ; resembling somewhat yellow topaz, but very different in crystallization and in absence of cleavage.
6. Smoky, Cairngorm Stone. Smoky-yellow to smoky-brown, and often transparent; but varying to brownish-black, and then nearly opaque in thick crystals. The color is due to organic compounds, according to Forster.
7. Milky. Milk-white and nearly opaque. Lustre often greasy, and then called Greasy quartz.
8. Cat's Eye (Katzenauge, Germ.). Exhibiting opalescence, but without prismatic colors, an effect due to fibres of asbestus.
9. Aventurine. Spangled with scales of mica or other mineral.
10. Impure from the presence of distinct minerals aistributed densely through the mass. The more common kinds are those in which the impurities are : (a) ferruginous, either red or jellow iron oxide; (b) chioritic, some kind of chlorite; (c) actinolitic ; (d) micaceous; (e) arenuceous, or sand. Quartz crystals also occur penetrated by various minerals, as topaz, corundum, chrysoberyl, garnet, different species of the hornblende and pyroxene groups, rutile, hematite, göthite, etc., etc.

Containing liquids in cavities. These liquids are seen to move with the change of position of the crystal, provided an air-bubble be present in the cavity. The liquid is either water (pure, or a mineral solution), carbon dioxide, or some petroleum-like or other compound.

## B. Cryptocrystalline Varieties.

1. Chalcedony. Having the lustre nearly of wax, and either transparent or translucenw. Color white, grayish, pale-brown to dark-brown, black; tendon-color common; sometimes delicate blue. Also of other shades, and then having other names. Often nammillary, botryoidal, stalactitic, and occurring lining or filling cavities in rocks. It is true quartz, with some disseminated opal.
2. Carnelinn. A clear red chalcedony, pale to deep in shade; also brownist-red to brown, the latter kind reddish-brown by transmitted light.
3. Chrysoprase. An apple-green chalcedony, the color due to the presence of nickel oxide.
4. Prase. Translucent and dull leek-green; so named from $\pi \rho \dot{c} \sigma \sigma v$, a leek. Always regarded as a stone of little value. The name is also given to crystalline quartz of the same color.
5. Plasma. Rather bright-green to leek-green, and also sometimes nearly emerald-green, and eubtranslucent or feebly translucent; sometines dotted with white. Heliotrope, or Blo aidsione, is the same stone essentially, with small spots of red jaspfr, looking like drops of blook.
6. Agate. A variegated chalcodony. The colors are either banded or in clouds, or due to visible impurities, a. Bunciel. The bands are delicate parallel lines, of white, tendon-like, wax-like, pale and dark-brown, and black colors, and sometimes bluish and other shades. They follow waving or zigzag courses, and are occasionally concentric circular, as in the eyeagate. The bands are the edges of layers of deposition, the agate having been formed by a deposit of silica from solutions intermittently supplied, in irregular cavities in rocks, and
deriving their concentric waving courses from the irregularities of the walls of the cavity Owing also to the unequal porosity, agates may be varied in color by artificial means. $\beta$. Ir regularly clouded. The colors various, as in banded agate. . $\gamma$. Colors due to visible impurities, including Moss-agate, filled with brown moss-like or dendritic forms distributed through the mass; Dendritic Agate, containing brown or black dendritic markings. There is also Agatized wood: wood petrified with clouded agate.
7. Onyx. Like agate in consisting of layers of different colors, but the layers are in even planes, and the banding therefore straight, and hence its use for cameos, the head being cut in one color, and another serving for the background. The colors of the best are perfectly well defined, and either white and black, or white, brown and black alternate.
8. Sardonyx. Like onyx in structure, but includes layers of carnelian (sard) along with others of white or whitish, and brown, and sometimes black colors.
9. Jasp:r. Impure opaque colored quartz. (a) Red iron sesquioxide being the coloring matter. (b) Brownish, or ochre-yellow, colored by hydrous iron sesquioxide, and becoming red when so heated as to drive off the water. (c) Dark-green and brownish-green. (d) Grayishblue. (e) Blackish or brownish-black. (f) Striped or riband jasper (Bandjaspis, Germn.), having the colors in broad stripes. (g) Egyptian jasper, in nodules which are zoned in brown and yellowish colors. Porcelain jasper is nothing but baked clay, and differs from true jasper in being B.B. fusible on the edges. Red porphyry, or its base, resembles jasper, but is also fusible on the edges, being usually an impure feldspar.
10. Agate-Jasper. An agate consisting of jasper with veinings and cloudings of chalcedony.
11. Siliceous sinter. Irregularly cellular quartz, formed by deposition from waters containing silica or soluble silicates in solution.
12. F'lint (Feuerstein, Germ.). Somewhat allied to chalcedony, but more opaque, and of dull colors, usually gray, smoky-brown, and brownish-black. The exterior is often whitish, from mixture with lime or chalk, in which it is imbedded. Lustre barely glistening, subvitreous. Breaks with a deeply conchoidal fracture, and a sharp cutting edge. The tlint of the chalk formation consists largely of the remains of infusoria (Diatoms), sponges, and other marine productions. The coloring matter of the common kinds is mostly carbonaceous matter.
13. Hornstone (Hornstein, Germ.). Resembles flint, but more brittle, the fracture more splintery. Chert is a term often applied to hornstone, and to any impure flinty rock, including the jaspers.
14. Basanite, Lydian Stone or Touchstone. $\Lambda$ velvet-black siliceous stone or flinty jasper, used on account of its hardness an I black color for trying the purity of the precious metals. The color left on the stone after rubbing the metal across it indicates to the experienced eye the amount of alloy. It is not splintery like hornstone.

Pyr., etc.-B.B. unaltered; with borax dissolves slowly to a clear glass; with soda dissolves with effervescence; unacted upon by salt of phosphorus. Insoluble in hydrochloric acid, and only slightly acted upon by solutions of fixed caustic alkalies. When fused and cooled it becomes opal-silica, having G. $=22$.

Diff.-Quartz is distinguished by its hardness-scratching glass with facility; infusibility -not fusing before the blowpipe ; insolubility-not attacked by water or the acids; unclenva-bility-one variety being tabular, but proper cleavage never being distinctly observed. To these characteristics the action of soda B.B. may be added.

Obs.-Quartz occurs as one of the essential constituents of granite, syenite, gnei:s. mica schist, and many relate l rocks; as the principal constituent of quartz-rock and many sandstones; as an unessential ingredient in some trachyte, porphyry, etc.; as the vein-stone in various rocks, and for a large part of mineral veins; as a foreign mineral in the cavities of trap, basalt, and related rocks, some limestones, etc., making geodes of crystals, or of chalcedony, agate, carnelian, etc.; as imbedded nodules or masses in various limestones, constituting the flint of the chalk formation, the hornstone of other limestones-these nodules sometimes becoming continuous layers; as masses of jasper occasionally in limestone. It is the principal material of the pebbles of gravel beds, and of the sands of the sea-shore and sand beds everywhere. Silica also occurs in solution (but mostly as a soluble alkaline silicate) in heated natural waters, as those of the Geysers of Iceland, New Zealand, and Californma, and the Yellowstone Park, and very sparingly in many cold mineral waters.

Switzerland, Dauphiny, Piedmont, the Carrara quarries, and numerous other foreign localities, afford fine specimens of rock crystal. Amethysts are brought from India, Ceylon, and Persia, also Transylvania. The amygdaloids of Iceland and the Faroe Islands, afford magnificent specimens of chalcedony; also Hüttenberg and Loben in Carinthia. etc. The finest carnelians and agates are found in Arabia, India. Brazil, Surinam, Oberstein, and Saxony. Cat's eye, in Ceylon, the coast of Malavar, and also in the Harz and Bavaria. Heliotrope, im Bucharia, Ta tary, Siberia.

In New York, quartz crystals are abundant in Herkimer Co. Fine dodecahedral crystale, at the beds of specular iron in St. Lawrence Co. In Antwerp, Jefferson Co., at Diamond Island and Diamond Point, Lake George, Pelham and Chesterfield, Mass., Paris and Perry, Me., Benton, N. H., Sharon, Vt., Meadow Mount, Md., and Hot Springs, Ark., are other localities of quartz crystal. For other localities, see the catalogue of localities in the latter part of this volume.

Rose quartz, at Albany and Paris, Me., Acworth, N. H., and elsewhere; smoky quartz, at Goshen, Mass., Richmond Co., N. Y., Pike's Peak, Colorado, etc. ; amethyst, at Keweenaw Point and Thunder Bay, etc., Lake Superior; also at Bristol, Rhode Island, near Greensboro, N. C. ; Specimen Mountain, Yellowstone Park. Crystallized green quariz, at Providence, Delaware Co., Penn.; at Ellenville, N. Y. Chalcedony and agates about Lake Superior, the Mississippi, and the streams to the west, etc. Red jasper is found in pebbles on the banks of the Hudson at Troy; red and yellow, near Murphy's, Calaveras Co., Cal. Heliotrope occupies veins in slate at Bloomingrove, Orange Co., N. Y.

Several varieties of this species have long been employed in jewelry. The amethyst has always been esteemed for its beanty. Cameos are in general made of onyx, which is well fitted for this kind of miniature sculpture. Jasper admits of a brilliant polish, and is often formed into vases, boxes, knife-handles, etc. It is also extensively used in the manufacture of Florentine mosaics. The carnelian is often rich in color, but is too common to be much esteemed; when first obtained from the rock they are usually gray or grayish-red; they receive their fine colors from an exposure of several weeks to the sun's rays, and a subsequent heating in earthen pots. The colors of agate, when indistinct, may be brought out by boiling in oil, and afterward in sulphuric acid; the latter carbonizes the oil absorbed by the porous layers, and thus increases the contrast of the different colors.

## TRIDYMITE.*

Hexagonal. $1 \wedge 1=124^{\circ} 3^{\prime}$ (basal); $1 \wedge 1=127^{\circ} 35^{\prime}$ (terminal); $d=$ $1 \cdot 6304$ (v. Rath). Cleavage $O$, imperfect. Crystals minute, commonly tabular (f. 507), formed by the prism and basal plane ; also frequently in twins and trillings with (1) $\frac{1}{6}$, and (2) $\frac{3}{4}$ as the twinning planes. Double refraction positive. $\mathrm{H}=7$. G. $=2 \cdot 282-2 \cdot 326$. Lustre vitreous, on the face pearly. Colorless, becoming white on weathering. Fracture conchoidal.

Comp.-Pure silica, or $\mathrm{SiO}_{2}$, like quartz.
Pyr.-B. B. infusible. Fuses in soda with effervescence, forming a colorless glass. Soluble is a boiling saturated solution of sodium carbonate.

Obs.-First found in cavities in the trachyte from Cerro St. Cristoval, near Pachucn, Mexico. Also in the trachyte of the Siebengebirge, and in related rocks from many localities. Forming on one occasion the mass of white volcanic ashes, from the island Vulcano. Also in microscopic crystals inclosed in opal, and in quartz.

Asmanite (Maskelyne).-A third form of silica, crystallizing in the orthorhombic system, "isomorphous with brookite." $H .=5 \cdot 5$. G. $=2 \cdot 245$. Found in very minute crystalline grains, generally rounded, in the meteoric iron of Breitenbach.

## OPAL.

Massive, amorphous; sometimes small reniform: stalactitic, or large tuberose. Also earthy.
H. $=5 \cdot 5-6 \cdot 5$. G. $=1 \cdot 9-2 \cdot 3$. Lustre vitreous, frequently subvitreous: often inclining to resinous, and sometimes to pearly. Color white, yellow,
red, brown, green, gray, generally pale; dark colors arise from foreigu aủmixtures; sometimes arich play of colors, or different colors by refracted and reflected light. Streak white. Transparent to nearly opaque.

Comp.-Silica, $\mathrm{SiO}_{2}$, as for quartz, the opal condition being one of lower degrees of hardsess and specific gravity. Water is usually present, but it is regarded as unessential. It varies in amount from 2 to 21 p. c.; or, mostly, from 3-9 p. c.

Var.-1. Precious Opal. Exhibits a play of delicate colors, or, as Pliny says, presents various refulgent tints in succession, reflecting now one hue and now another. Seldom larger than a hazel-nut. Donbly refracting (biaxial), Behrens.
3. Fire-opal. Hyacinth-red to honey-yellow colors, with fire-like reflections somewhat irised on turning.
3. Girasol. Bluish-white, translucent, with reddish reflections in a bright light.
4. Common Opal. In part translucent; (a) milk-white to greenish, yellowish, bluish; (b) Resin-opal (Wachsopal, Pechopal, Germ.), wax-, honey- to ochre-yellow, with a resinous lustre; (c) dull olive-green and mountain-green; (d) brick-red.
5. Cuchoiong. Opaque, bluish-white, porcelain-white, pale-yellowish or reddish; often adheres to the tongue, and contains a little alumina.
6. Opal-agato. Agate-like in structure, but consisting of opab of different shades of color.
7. Jasp-opal. Opal containing some yellow iron sesquioxide and other impurities, and having the color of yellow jasper, with the lustre of common opal.
8. Wood-opal (Holzopal, Germ.). Wood petrified by opal.
9. Hyclite. Clear as glass and colorless, constituting globular concretions, and also crusts with a globular, reniform, botryoidal, or stalactitic surface; also passing into translucent, and whitish.
10. Fiorite, Siliceous Sinter. Includes translucent to opaque, grayish, whitish, or brownish incrustations, powous to firm in texture ; sometimes fibrous-like or filamentous, and, when so, pearly in lustre, formed from the decomposition of the siliceous minerals of volcanic rocks about fumaroles, or from the siliceous waters of hot springs. It graduates at times into hyalite. Geyserite constitutes concretionary deposits about the Iceland and Yellowstone (pealite) geysers, presenting white or grayish, porous, stalactitic, filamentous, cauliflowerlike forms; also compact-massive, and scaly-massive; $\mathrm{H} .=5$; rarely transparent, usually opaque; sometimes falling to powder on drying in the air.
11. F'loat-stone. In light concretionary or tuberose masses, white or grayish, sometimes cavernous, rough in fracture. So light, owing to its spongy texture, as to float on water. T'he concretions sometimes have a flint-like nucleus.
12. Tripolite. Formed from the siliceous shells of Diatoms and other microscopic species, as first made known by Ehrenberg, and occurring in deposits, often many miles in area, either uncompacted, or moderately hard. Infusolial Eurth, or Eirthy T'ripolitt, a very fine-grained earth looking often like an eartny chalk, or a clay, but harsh to the feel, and scratching glass when rubbed on it.

Pyr., etc.-Yields water. B.B. infusible, but becomes opaque. Some yellow varieties, oontaining iron, turn red.

Obs.-Occurs filling cavities and fissures or scams in igneous rocks, porphyry, and some metallic veins. Also imbedded, like Hint, in limestone; and sometimes, like other quartz concretions, in argillaceous beds; also formed from the siliceous waters of some hot springs; also resulting from the mere acoumulation, or accumulation and partial solution and solidification, of the siliceous shells of infusoria-which consist essentially of opal-silica.

Precious opal occurs in Hungary ; in Honduras; and Mexico. Five opal occurs at Zimapan in Mexico ; Farüe; near San Antonio, Honduras. Common opal is abundant at Telkebanya in Hungary; in Moravia; in Bohemia; Stenzelberg in the Siebengebirge; Faröe, Iceland; the Giant's Causeway, at many localities. In U. S., hyavite occurs sparingly in N. York, at the Phillips ore bed, Putnam Co.; in Georgia, in Burke and Scriven Cos.; in Washington Co., good fire opal. At the Geysers on the Fire Hole river, Yellowstone Park, geyserite is abundant.

The precious opal, when large, and exhibiting its peculiar play of colors in perfection, is a gem of high value. It is cut with a convex surface.

Melanophlogite (Lasaulx).-Occurs in minute, colorless, cubes coating sulphur crystala from Girgenti, Sicily. Contains $\mathrm{SiO}_{2} 86 \cdot 3$ p. c., $\mathrm{SO}_{3} 7 \cdot 2, \mathrm{H}_{2} \mathrm{O} 2 \cdot 9$; chemical nature doubtful. Turns black upou ignition, hence the name.

## II. TERNARY OXYGEN COMPOLINDS.

## 1. SILICATES.-A. ANHYIIROUS SILICATES.

a. Bisilicates. General Formula $\mathrm{RSiO}_{3}$.
(a) Amphibole Group. Pyroxene Section.
enstatite. Bronzite. Protobestite.
Orthorhombic. $I \wedge I=88^{\circ} 16^{\prime}$ and $91^{\circ} 44^{\prime}$ (Breitenbach meteorite, $v$.

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Bamle, Norway. Lang); $\dot{c}: \bar{b}: \breve{a}=0.58853: 1.03086: 1$. Cleavage: $I$, easy; $i-\zeta, i-\bar{\imath}$, less so. Sometimes a fibrous appearance on the cleavage-surface. Also massive and lamellar. $\mathrm{H} .=5 \cdot 5$. G. $=3 \cdot 1-3 \cdot 3$. Lustre a little pearly on cleavage-surfaces to vitreons; often metalloidal in the bronzite variety. Color grayish-white, yellowish-white, greenish-white, to olive-green and brown. Streak uncolored, grayish. Double refraction positive ; opticaxial plane brachydiagonal ; axes very divergent.

Comp., Var. $-\mathrm{MgSiO}_{3}=$ Silica 60, magnesia $40=100$; also ( $\mathrm{Mg}, \mathrm{F}$ e) $\mathrm{SiO}_{3}$.
Var. 1. With little or no iron; Enstatite. Color white, yellowish, grayish, or greenishwhite; lustre pearly-vitreous; G. $=3 \cdot 10-3 \cdot 13$. Chladnite, which makes up 90 p. c. of the Bishopville meteorite, belongs here and is the purest kind; Victorite (Meunier), from the Deesa (Chili) meteoric iron is probably identical.
2. Ferriferous; Bronzite. Color grayish-green to olive-green and brown; lustre of cleav-age-surface adamantine pearly to submetallic or bronze-like. The ratio of $\mathrm{Mg}:$ Fe varies from 11:1 to 3:1. Analysis of bronzite from Leiperville by Pisani, $\mathrm{SiO}_{2} 57.08, \mathrm{AlO}_{3} 0.28$, $\mathrm{FeO} 5 \cdot 77$, $\mathrm{MgO} 35 \cdot 59, \mathrm{H}_{2} \mathrm{O} 0 \cdot 90=99 \cdot 62$.
Pyr., etc.-B.B. almost infusible, being only slightly rounded on the thin edges; F.=6. Insoluble in hydrochloric acid.
Diff.-Distinguished by its infusibility from varieties of amphibole, which it resembles.
Obs.-Occurs near Aloysthal in Moravia; in the Vosges; at Kupferberg in Bavaria; at Baste in the Harz (l'rotobustite); in the chrysolite bombs in the Eifel; in immense crystals with apatite, near Bamle, Norway. In Pennsylvania, at Leiperville and Texas; at Brewster, N. Y. Bronzite is quite common in meteorites.

DesCloizeaux first defined the limits of this species, as here laid down.
Named from ' $\epsilon \nu \sigma \tau \alpha \dot{\prime} \tau \eta s$, an opponent, hecause so refractory. The name bronzite has priority, but a bronze lustre is not essential, and is far from universal.

## HYPERSTHENE.

Orthorhombic. $I \wedge I=91^{\circ} 32 \frac{1}{2}$, DesCloizeaux (Mt. Doré); $91^{\circ} 40^{\prime}$ v. Rath (amblystegite). Cleavage : i-乞 perfect, $I$ and $i-\bar{i}$ distinct but inter rupted. Usually foliated massive.
H. $=5-6$. G. $=3 \% 392$. Lustre somewhat pearly on a cleavage-surface, and sometimes a little metalloidal ; often with a peculiar iridescence due
to the presence of minute enclosed tabular crystals (brookite?) in parallel position (Kosmann). Color dark brownish-green, gray-ish-black, greenish-black, pinchbeck-brown. Streak grayish, brownish-gray. Translucent to nearly opaque. Brittle. Optic-axial plaue brachydiagonal ; axes very divergent; bisectrix negative.

Comp.-( $\mathrm{Mg}, \mathrm{Fe}^{2}$, $\mathrm{SiO}_{3}$ with $\mathrm{Fe}: \mathrm{Mg}=1: 5,1: 3$, etc. If Fe to $\mathrm{Mg}=1: 2$ the formula requires $\mathrm{SiO}_{2} 54 \cdot 2, \mathrm{FeO} 21 \cdot 7, \mathrm{MgO} 24 \cdot 1=100$.
Pyr., etc.-B.B. fuses to a black enamel, and on charcoal yields a magnetic mass. Partially decomposed by bydrochloric acid.
Obs.-Hypersthene occurs at Isle St. Paul, Labrador in Canada; at the Isle of Skye; in Greenland; Norway; Ronsberg in Bohemia; the Tyrol ; Elfdalen in Sweden; Laacher See (umblystegite); Voigtland ; in trachyte of Mt. Doré, Auvergne.

In chemical composition, enstatite (and bronzite), and hypersthene belong together, since they grade insensibly into each other; and in


Mt. Doré. crystalline form they are identical. The essential difference between them, according to DesCloizeaux, lies in the axial dispersion which is uniformiy $\rho<v$ for enstatite, and $\rho>v$ for hypersthene.

Diaclasite.-Near bronzite ; differs in optical characters. ( $\mathrm{Mg}, \mathrm{Fe}, \mathrm{Ca}$ ) $\mathrm{SiO}_{3}$. Harzburg; Guadarrama, Spain.

WOLLASTONITE. Tabular Spar. Tafelspath, Germ.
Monoclinic. $C^{\gamma}=69^{\circ} 48^{\prime}, I \wedge . I=87^{\circ} 28^{\prime}, O \wedge 2-i=137^{\circ} 48^{\prime} ; c \cdot b: a$ $=0.4338: 0.89789: 1$. Fig. 510 in the pyroxene or normal position, but with the edge $O / i-i$ the obtuse edge ; f. 511 in the position given the crystals by authors who make $i-i$ the plane $O$, and $2-i$ the plane $I . O \wedge-1-\dot{1}$ $=160^{\circ} 30^{\prime}, O \wedge 1-i=154^{\circ} 25^{\prime}, i-i \wedge-2=132^{\circ} \quad 54^{\prime}, i-i \wedge 2=93^{\circ} 52^{\prime}$. Rarely in distinct tabular crystals. Cleavage: $O$ most distinct; $i-i$ less so ; $1-i$ and $-1-i$ in traces. Twins: twinning-plane $i-i$. Usually cleavable massive, with the surface appearing long fibrous, fibres parallel or reticulated, rather strongly coherent.

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$\mathrm{H} .=4 \cdot 5-5 . \quad \mathrm{G} .=2 \cdot 78-2 \cdot 9$. Lustre vitreous, inclining to pearly upon the faces of perfect cleavage. Color white, inclining to gray, yellow, red, or brown. Streak white. Subtransparent-translucent. Fracture uneven, sonnetimes rery tough. Optic-axial plane $i-\grave{\imath}$; divergence $70^{\circ} 40^{\prime}$ for the red rays; bisectrix of the acute angle negative; inclined to a normal to $i-i$ $57^{\circ} 48^{\prime}$, and to a nermal to $O 12^{\circ}$, DesCl.

Comp.-CaSiU ${ }_{3}=$ Silica $51 \cdot 7$, lime $48 \cdot 3=100$.
Pyr., etc.-In the matrass no change. B.B. fuses easily on the edges; with some soda, a Hebby glass, with more, swells up and is infusible. With hydrochloric acid gelatinizes; most varieties effervesce slightly from the presence of calcite.

Diff.-Differs from asbestus, and tremolite in forming a jelly with acids, as also by its more vitreous fracture; fuses less readily than natrolite and scolecite; when pure does not effervesce with acids like the carbonates.

Obs.-Wollastonite is found in regions of granite and granular limestone; also in basalt and lavas. Occurs in Hungary ; in Finland; and in Norway; at Göckum in Sweden; in the Harz; at Auerbach, in granular limestone; at Vesuvius. In the U. S., in N. York, at Willsborough ; at Lewis; Diana, Lewis Co. In Penn., Bucks Co. At the Cliff Mine, Keweenaw Point, Lake Superior. In Canada, at Grenville.

## PYROXENE.

Monoclinic. $C=73^{\circ} 59^{\prime}, I \wedge I=87^{\circ} 5^{\prime}, O \wedge 2-\grave{i}=131^{\circ} 17^{\prime} ; \dot{c}: b: a$ $=0.5412: 0.91346: 1 . \quad O \wedge I=100^{\circ} 57^{\prime}, O \wedge-1-i=155^{\circ} 51^{\prime}$, $O \wedge 1-i$ $=148^{\circ} 35^{\prime}, O \wedge-1=146^{\circ} 9^{\prime}, O \wedge 1=137^{\circ} .49^{\prime},-1 \wedge-1=131^{\circ} 24^{\prime}$. Cleavage: I rather perfect, often interrupted; $i-i$ sometimes nearly per-

fect; $i-\imath$ imperfect; $O$ sometimes easy. Crystals usually thick and stont. Twins: twinning-plane $i-i$ (f. 521 ). Often coarse lamellar, in large masses, parallel to $O$ or $i-i$. Also granular, particles coarse or fine; and fibrous, fibres often fine and long.

H. $=5-6 . \quad \mathrm{G} \cdot=3 \cdot 23-3 \cdot 5$. Lustre itreous, inclining to resinous; some pearly. Color green of various shades, verging on one side to white or grayish-white, and on the other to brown and black. Streak white to gray and grayish-green. Transparent opaque. Fracture conchoidaluneven. Brittle: In crystals from Fassa, optic-axial plane $i-\grave{i}$; divergence $110^{\circ}$ to $113^{\circ}$; bisectrix of the acute angle positive, inclined $51^{\circ} 6^{\prime}$ to a normal to $i-i$ and $22^{\circ} \check{55^{\prime}}$ to a normal to $O, \mathrm{DesCl}$.

Comp., Var.-A bisilicate, having the general formula $\mathrm{RSiO}_{3}$, where R may be $\mathrm{Ca}, \mathrm{Mg}$, $\mathrm{Fe}, \mathrm{Mn}$, sometimes also $\mathrm{Zn}, \mathrm{Ka}_{2}, \mathrm{Na}_{2}$. Usually tiwo or more of these bases are present. The first three are most common; but calci 2 m is the only one that is present alvays and in large percentage. Besides the substitutions of the above bases for one another, these same bases are at times replaced by $\AA 1, \mp e, \nexists n$, though sparingly, and the silicon occasionally by aluminum.

The varieties proceeding from these isomorphous substitutions are many and diverse, and there are still others depending on the state of crystallization. The foliated and fibers kinds early received separate names, and for a while were regarded as distinct species. Frbrous or columnar forms are very much less common than in hornblende, and lamellar or foliated kinds more common. The crystals are rarely loug and slender, or bladed, like those of that species.

The most prominent division of the species is into (A) the non-aluminous;-(B) the aluminous. But the former of these groups shades imperceptibly into the latter. These two groups are generally subdivided according to the prevalence of the different protoxide elements. Yet here, also, the gradation from one series to another is in general by almost insensible shades as to composition and chemical characters, as well as all physical qualities.

## I. Containing little or no Alumina.

1. Lime-Magnesia Pyroxene; Malacolite. Diopside, Alalite, White Coccolite. Color white, yellowish, grayish-white to pale green. In crystals: cleavable and granular massive. Sometimes transparent and colorless. G. =3:2-3 \%8. Formula, $\mathrm{CaMgSi}_{2} \mathrm{O}_{6}=$ Silica $55 \%$, magnesia $18 \cdot 5$, lime $\rightleftharpoons 5.9$. Sometimes $\mathrm{Ca}: \mathrm{Mg}=1: 2$; less than 4 p . c. of iron are present.
2. Lime-Magnesia-Iron Pyroxene; SAhlite. Color grayish-green to deep green and black; sometimes grayish and yellowish-white. In crystals; also cleavable and granular massive G. $=3 \cdot 25-3 \cdot 4$. Named from Sala in Sweden, one of its localities, where the mineral occurs in masses of a grayish-green color, having a perfect cleavage parallel to the basal plane ( $O$ ). Formula $(\mathrm{Ca}, \mathrm{Mg}, \mathrm{Fe}) \mathrm{SiO}_{3}$. The ratio of $\mathrm{Ca}: \mathrm{Mg}: \mathrm{Fe}$ varies much, $=3: 3: 1,2: 2: 1$, etc. The ratio $=4: 3: 1$, corresponds to silica $53 \cdot 7$, magnesia $13 \cdot 4$, lime $24 \cdot 9$, iron protoxide $8 \cdot 0=100$.

Diallage. Part of the so-called diallage, or thin foliated pyroxene, belongs here, and the rest under the corresponding division of the aluminous pyroxenes. Color grayish-green to bright grass-green, and deep green; lustre of cleavage surface pearly, sometimes inetalloidal or brassy. $\mathrm{H} .=4$. $\mathrm{G}=3 \cdot 2-3 \cdot 35$. Composition near the preceding; analysis by vom Rath, Neurode, $\mathrm{SiO}_{2} 53.60, \mathrm{AlO}_{3} 1 \cdot 99, \mathrm{FeO} 8.9 \overline{5}, \mathrm{MnO} 0.28, \mathrm{MgO} 18.08, \mathrm{CaO} 21 \cdot 06, \mathrm{H}_{2} \mathrm{O} 0.86=99 \cdot 82$, With this variety belongs part also of what has been called lypersthene and bronzite-the part that is easily fusible. Common especially in serpentine rocks. Named from $\delta a \pi \lambda a c \gamma_{n} ;$ difference, in allusion to the dissimilar cleavages.
3. Iron-Lime Pyroxene. Hedenbergite. Color black. In crystals, and also lamellar massive ; cleavage easy parallel to $i-i . \quad \mathrm{G} .=35-3 \cdot 58$. Formula $\mathrm{CaFeSi}_{2} \mathrm{O}_{6}$ ( Mg being absent) $=$ Silica 4839 , lime $22 \cdot 18$, iron protoxide $29 \cdot 43=100$. Asteroite is a similar pyroxene containing also Mn (Igelström), Sweden.
4. Lime-Iron-Manganese-Zine Pyroxene; Jeffersonite. Color greenish-black. Crystals often very large ( $3-4 \mathrm{in}$. thick), with the angles generally rounded, and the faces uneven, as if corroded. G. $=3 \cdot 36$. Analysis, Franklin, N. J., by Pisani, $\mathrm{SiO}_{i} 45 \cdot 95, \mathrm{AlO}_{3} 0.85, \mathrm{FeO}$ 8.31, $\mathrm{MnO} 10 \cdot 20, \mathrm{ZnO} 10 \cdot 15, \mathrm{CaO} 21 \cdot 55, \mathrm{MgO} 3 \cdot 61$, ign $0 \cdot 35=101 \cdot 57$.

## II. Aluminous.

Aluminous Lime-Magnesia Pyroxene; Levcaugrte (Dana). Color white or grayish. Analysis, Bathurst, C., by Hunt, $\mathrm{SiO}_{2} 51 \cdot 50, \mathrm{AlO}_{3} 6 \cdot 15, \mathrm{FeO}_{3} 0 \cdot 35, \mathrm{MgO} 17 \cdot 69, \mathrm{CaO} 23 \cdot 80$. $\mathrm{H}_{2} \mathrm{O} 1 \cdot 10=100 \cdot 59$. Looks like diopside. H. $=6 \cdot 5$. G. $=3 \cdot 19$. Hunt. Named from $\lambda \varepsilon v \kappa o \rho$; white.

Aluminous Sime-Magnesia-Iron Pyroxene; Fassaite, Augrte. Color clear deep-green to greenish-black and black; in crystals, and also massive; subtranslucent to opaque. G. $=3 \cdot 25-3 \cdot 5$. Contains iron, with calcium and magnesium, also aluminum. Analysis of augite from Montreal by Hunt, $\mathrm{SiO}_{2} 49 \cdot 40, \mathrm{AlO}_{3} 6 \cdot 70, \mathrm{HeO}_{3} 7 \cdot 83, \mathrm{MgO} 13 \cdot 06, \mathrm{CaO} 21 \cdot 88, \mathrm{Na}_{2} \mathrm{O} 0.74$, $\mathbf{H}_{2} \mathbf{O} 0 \cdot 50=100 \cdot 11$.
a. Fassaite (or Pyrgom). Includes the green kinds found in metamorphic rocks. Named from the locality at Fassa in Piedmont, which affords deep-green crystals, sometimes pistachiogreen, like the epidote of the locality.
b. Augite. Includes the greenish or brownish-black and black kinds, occurring mostly in eruptive rocks, but also in metamorphic. Named from ávýn, lustre.

Pyr., etc.-Varying widely, owing to the wide variations in composition in the different varieties, and often by insensible gradations. Fusibility, from the almost infusible diallage to 3.75 in diopside ; 3.5 in sablite; 3 in jeffersonite and augite; 2.5 in hedenbergite. Varieties rich in iron afford a magnetic globule when fused on charcoal, and in general their fusibility varies with the amount of iron. Jeffersonite gives with soda on charcoal a reaction for zinc and manganese; many others also give with the fluxes reactions for manganese. Most varieties are unacted upon by acids.

Diff.-See Amphibole, p. 297.
Obs.-Pyroxene is a common mineral in crystalline limestone and dolomite, in serpentine, and in volcanic rocks; and occurs also, but less abundantly, in connection with granitic rocks and metamorphic schists. The pyroxene of limestone is mostly the white and light-green or gray varieties; that of most other metamorphic rock, sometimes white or colorless, but usually green of different shades, from pale green to greenish-black, and occasionally black; that of serpentine is sometimes in fine crystals, but often of the foliated green kind called diallage; that of eruptive rocks is the black to greenish-black augite.

Prominent foreign localities are : malacolite (diopside), Traversella, Ala in Piedmont; Sala, Tunaberg. Sweden; Pargas; Achmatovsk; etc. Sallitite, Sala; Arendal; Degeröe; Schwarzenberg; etc. Hedenbergite, Tunaberg; Arendal. Augite, Fassathal; Vesuvius; etc.-in most dolerytic igneous rocks.

In N. America common (see list of localities at the close of the volume)., Some localities are: In Mass., at the Bolton quarries. In Conn., at Canaan. In N. York, at Warwick, Monroe, Edenville, Diana. In N. Jersey, in Franklin. In Penn., near Attleboro'. In Canada, at Bytown, at Calumet I., at Grenville.

Acmite. - Monoclinic. In slender pointed crystais (hence name) in quartz. H. =6. G. $=$ $3 \cdot 2-3 \cdot 53$. Color brownish to reddish-brown, in the fracture blackish-green. Opaque. Fracture uneven. Brittle. $\mathrm{ISSiO}_{3}, \mathrm{R}=\mathrm{Na}_{2}, \mathrm{Fe}$, or $\mathrm{Fe}(\mathrm{Fe}=3 \mathrm{R})$; analysis by Rammelsberg, $\mathrm{SiO}_{2}$ $51 \cdot 66, \mathrm{FeO}_{3} 28 \cdot 28$, $\mathrm{FeO} 5 \cdot 23$, $\mathrm{MnO} 0 \cdot 69$, $\mathrm{Na}_{2} \mathrm{O} 12 \cdot 46, \mathrm{~K}_{2} \mathrm{O} 0 \cdot 43$, TiO $1 \cdot 11$, ign $0 \cdot 39=100 \cdot 25$ Kongsberg, Norway.

EGIRITE.-Near pyroxene in form, but contains alkalies. H. $=5 \cdot 5-6$. G. $=3 \cdot 45-3 \cdot 58$. Color greenish-black. Subtranslucent to opaque. Analysis Ramm., Brevig, $\mathrm{SiO}_{0} 50 \cdot 25, \mathrm{AlO}_{3}$ $1 \cdot 22, \mathrm{FeO}_{3} 22 \cdot 07, \mathrm{FeO} 8 \cdot 80, \mathrm{MnO} 1 \cdot 40, \mathrm{CaO} 5 \cdot 47$, $\mathrm{MgO} 1 \cdot 28, \mathrm{Na}_{2} \mathrm{O} 929, \mathrm{~K}_{2} \mathrm{O} 0.94=109 \cdot 72$. Also from Magnet Cove, Arkansas.

## RHODONITE.

Triclinic, but approximately isomorphous with pyroxene. Cleavage: $I$ perfect; $O$ less perfect. Usually massive.

H. $=5 \cdot 5-6 \cdot 5$. G. $=3 \cdot 4-3 \cdot 68$. Lustre vitrenus. Color light brownish-red, flesh-red, sometimes greenish or yellowish, when impure ; often black outside from exposure. Streak white. Transparent-opaque. Fracture conchoidal-uneven. Very tough when massive.

Comp., Var. $-\mathrm{MnSiO}_{3}=$ Silica $45 \cdot 9$, manganese protoxide $54 \cdot 1=$ 100. Usually some Fe and Ca , and occasionally Zn replace part of the Mn. Ordinary. (a) Crystallized. Either in crystals or foliated. The ore in crystals from Paisberg, Sweden, was named Paisbergite under the idea that it was a distinct species. (b) Granular massive. Calciferous; Bustamite. Contains 9 to 15 p. c. of lime replacing part of the manganese. Often also impure from the presence of caloium carbonate, which suggests that part of the lime replacing the manganese may have come from partial alteration. Grayish-red. Zinciferous; Fowlerite. In crystals and foliated, the latter looking much like cleavable red feldspar ; the crystals sometimes half an inch to an inch through. $I \wedge I=86^{\circ} 30^{\prime}$, Torrey. G. $=3 \cdot 44$, Thomson.
Pyr., etc.-B.B. blackens and fuses with slight intumescence at 2.5 ; with the fluxes gives reactions for manganese ; fowlerite gives with soda on charcoal a reaction for zinc. Slightly acted upon by acids. The calciferous varieties often effervesce from mcchanical admixture with calcium carbonate. In powder, partly dissolves in hydrochloric acid, and the in soluble part becomes of a white color. Darkens on exposure to the air, and sometimes bncomes nearly black.
Obs.-Occurs at Longban, near Philipstadt in Sweden; also in the Harz ; in the district of

Katherinenberg in the Ural ; in Cornwall, etc. Occurs in Warwick, Mass. ; Blue Hill Bay, Maine ; near Hinsdale, N. H. ; fowlerite (keatingine) at Hamburg and Sterling, New Jersey. Named from $\rho 6 \delta o v$, a rose, in allusion to the color.
Babingtonite.-Triclinic. $9 \mathrm{RSiO}_{3}+\mathrm{FeSi}_{3} \mathrm{O}_{9}$, with $\mathrm{R}=\mathrm{Fe}(\mathrm{Mn}): \mathrm{Ca}(\mathrm{Mg})=2: 3$ (Ramm.). Analysis, Rammelsberg, $\mathrm{SiO}_{2} 51 \cdot 22, \mathrm{FeO}_{3} 11 \cdot 00, \mathrm{FeO} 10 \cdot 26, \mathrm{MnO} 7 \cdot 91, \mathrm{MgO} 0 \cdot 77, \mathrm{CaO}$ $19 \times 32$, ign $=0 \cdot 44=100 \cdot 92$. Color greenish-black. Arendal; Nassau; Devonshire; Baveno.

SPODUMENE.*
Monoclinic. $C=69^{\circ} 40^{\prime} I \wedge I=87^{\circ}, O \wedge 2-\grave{\imath}=130^{\circ} 30^{\prime}$. Cryotals large. Cleavage: $i-i$ very perfect; $I$ also perfect; $1-i$ in traces; in striæ on $i-i$. Twins: twimning-plane $i-i$. Also massive, with broad clearage surface.
$\mathrm{H} .=6 \cdot 5-7 . \quad \mathrm{G} .=3 \cdot 13-3 \cdot 19$. Lustre pearly. Cross fracture vitreous. Color grayish-green, passing into greenish-white and grayish-white, rarely faint-reddish. Streak uncolored. Translucent-subtranslucent. Fracture uneven.

Comp. $-3 \mathrm{RSiO}_{3}+4 \mathrm{AlSi}_{3} \mathrm{O}_{9} ; \mathrm{R}=\mathrm{Li}_{2}$ mostly. Silica 642 , alumina $29 \cdot 4$, lithia $6 \cdot 4=100$. Sometimes $\mathrm{Li}: \mathrm{Na}(\mathrm{K})=20: 1$, Ramm.

Pyr., etc.-B.B. becomes white and opaque, swells up, imparts a purple red color (lithia) to the flame, and fuses at 3.5 to a clear or white glass. The powdered mineral, fused with a mixture of potassium bisulphate and fluor on platinum wire, gives a more intense lithia reaction. Not acted upon by acids.

Diff.-Distinguished by its perfect orthodiagonal as well as prismatic, cleavage; has a higher specific gravity and more pearly


Norwich, Mass. lustre than feldspar or scapolite. Gives a red flame B.B.

Obs.-Occurs on the island of Utö, Sweden; near Sterzing and Lisens in the Tyrol; at Killiney Bay, near Dublin, and at Peterhead in Scotland. At Goshen, Mass. ; also at Chesterfield and Norwich, Mass. ; at Windham, Maine ; at Winchester, N. H.; at Brookfield, Ct.

Petalite.- $3 \mathrm{Li}_{2} \mathrm{Si}_{2} \mathrm{O}_{5}+4 \mathrm{AlSi}_{8} \mathrm{O}_{15}=$ Silica 77.97 , alumina $17 \cdot 79$, lithia 3.57 , soda $0.67=$ 100. Ramm. Q. ratio $\mathrm{Li}: \mathrm{Al}: \mathrm{Si}=1: 4: 20$, or for bases to silicon $=1: 4$. H. $=6-6{ }^{\circ}$. G. =2.5. Colorless; white. Utö, Swedeu; Elba (castoritc); Bolton, Mass.

## Amphibole Section.

## ANTHOPHYLLITE.

Orthorhombic. $I \wedge I=125^{\circ}$ to $125^{\circ} 25^{\prime \prime}$. Cleavage: $i-\bar{i}$ perfect, $I$ less so, $i-\check{\imath}$ difficult. Commonly lamellar, or fibrous massive; fibres often rery slender.
$\mathrm{H} .=5 \cdot 5$. G. $=3 \cdot 1-3 \cdot 2$. Lustre somewhat pearly upon a cleavage surface. Color brownish-gray, yellowish-brown, brownish-green, sometimes submetallic. Streak uncolored or grayish. Translucent to subtranslucent. Brittle. Double refraction positive; optical axes in the brachydiagonal section.

Comp-( $\left.\mathrm{Fe}, \mathrm{Mg}_{\mathrm{g}}\right) \mathrm{SiO}_{3}, \mathrm{Fe}: \mathrm{Mg}=1: 3=$ Silica 55.5 , magnesia 27.8 , iron protoxide $16 \%=$ 100.

Pyr., etc.-B.B. fuses with great difficulty to a black magnetic enamel; with the fluxea gives reactions for iron; unacted upon by acids.

Obs.-Occurs near Kongsberg in Norway, and near Modum. Also at Hermannschlag. Moravia.

Anthophyllite bears the same relation to the Amphibole Group that enstatite and hypersthene do to the Pyroxene Group.

Kupfferite.-Probably $\mathrm{MgSiO}_{3}$, with a little $\mathrm{Fe} . ~ I \wedge I=124^{\circ} 30^{\prime}$, hence an enstatite-horn. blende. Color emerald-green (chrome). Tunkinsk Mts., Miask. Analysis of a similar mineral from Perth, Canada, Thomson, $\mathrm{SiO}_{2} 57 \cdot 60, \mathrm{AlO}_{3} 3 \cdot 20$, $\mathrm{FeO} 2 \cdot 10, \mathrm{MgO} 29 \cdot 30$, $\mathrm{CaO} 3 \cdot 55$. igh. $3 \cdot 5 \overline{5}=99 \cdot 30$.

## AMPHIBOLE.* Hornblende.

Monoclinic. $\quad C=75^{\circ} 2^{\prime}, I \wedge I=124^{\circ} 30^{\prime}, O \wedge 1-\grave{\imath}=164^{\circ} 10^{\prime}, \dot{c}: \bar{b}: \grave{a}$ $=0.5527: 1.8825: 1$. Crystals sometimes stout, often long and bladed. Clearage: TT highly perfect ; $i-i, i-i$ sometimes distinct. Lateral planes often longitudinally striated. Twins: twimning-plane $i-i$, as in $f$. 527 (simple form f. 526), and 530. Imperfect crystallizations: fibrous or columnar, coarse or fine, fibres often like flax; sometimes lamellar; also granular massive, coarse or fine, and usually strongly coherent, but sometimes friable.

H. $=5-6$. G. $=2 \cdot 9-3 \cdot 4$. Lustre vitreous to pearly on cleavage-faces; fibrous varieties often silky. Color between black and white, throngh various shades of green, inclining to blackish-green. Streak uncolored, or paler than color. Sometimes nearly transparent; usually subtranslucent-opaque. Fracture subenchoidal, uneven. Bisectrix, in most varieties, inclined about $60^{\circ}$ to a normal to $O$, and $15^{\circ}$ to a normal to $i-i$; and donble refraction negative.

[^38]
## T. Containing little or no alumina.

Magnesit- Lime Amphibole; Tremolite. Grammatite. Colors white to dark-gray. In distinct crystals, either long bladed or short and stout; long and thin columnar, or fibrous; also compact granular massive. $1 \wedge I=124^{\circ} 30^{\prime} . \quad \mathrm{H} .=5 \cdot 0-6 \cdot 5$. G. $=2 \cdot 9-3 \cdot 1$. Sometimes transparent and colorless. Contains magnesia and lime with little or no iron; formula (Ca, $\mathrm{Mg}) \mathrm{SiO}_{3}, \mathrm{Ca}: \mathrm{Mg}=1: 3=$ Silica $57 \cdot 70$, magnesia $28 \cdot 85$, lime $13 \cdot 3 \overline{5}=100$. Named Tremolite by Pini, from the locality at Tremola in Switzerland.

Nepirite.-In part a tough, compact, fine grained tremolite, having a tinge of green or blue, and breaking with a splintery fracture and glistening lustre. $H .=6-6 \cdot 5$. G. $=2 \cdot 96-3 \cdot 1$. Named from a supposed efficacy in diseases of the kidney, from veфpós, kidney. It occurs usually associated with talcose or magnesian rocks. Nephrite or jade was brought in the form of carved ornaments from Mexico or Peru soon after the discovery of America. A similar stone comes from China and New Zealand.

A nephrite-like mineral, called bowenite, from Smithfield, R. I., having the hardness 5.5 is serpentine in composition. The jade of de Saussure is the saussurite (see under Zoisite) of the younger de Saussure. Another aluminous jade has been called jadeite (q.v.) by Damour.

Magnesia-Lime-Iron Amphibole; Actinolite. Strahlstein, Germ. Color bright-green and grayish-green. In crystals, either short or long-bladed, as in tremolite; columnar or fibrous; granular massive. G. $=3-32$. Sometimes transparent. Contains magnesia and lime, with some iron protoxide, but seldom more than 6 p. c. ; formula ( $\mathrm{Ca}, \mathrm{Mg}, \mathrm{Fe}$ ) $\mathrm{SiO}_{3}$. The variety in long bright-green crystals is called glassy actinolite; the crystals break easily across the prism. The fibrous and radiated kinds are often called asbestiform actinolite and radiated actinolite. Actinolite owes its green color to the iron present.

Iron-Magnesia Amphibole; Cummingtonite. Color gray to brown. Usually fibrous or fibro-lamellar, often radiated. G. $=3 \cdot 1-3 \cdot 32$. Contains much iron, with some magnesia, and little or no lime. Formula ( $\mathrm{Fe} . \mathrm{Mg}$ ) $\mathrm{SiO}_{3}$. Named from the locality, Cummington, Mass.

Asbestus. Tremolite, actinolite, and other varieties of amphibole, excepting those coutaining much alumina, pass into fibrous varieties, the fibres of which are sometimes very long, fine, flexible, and easily separable by the fingers, and look like flax. These kinds, like the corresponding of pyroxene, are called asbestus (fr. the Greek for incombustibse). The colors vary from white to green and wood-brown. The name amianthus is now applied usually to the finer and more silky kinds. Much that is so called is chrysotile, or fibrous serpentine, it containing 12 to 14 p . c. of water. Mountain leather is a kind in thin flexible sheets, made of interlaced fibres; and mountdin cork (Bergkork) the same in thicker pieces; both are so light as to float on water, and they are often hydrous. Mountain wood (Bergholz, Holzashest, Germ ) is compact fibrous, and gray to brown in color, looking a little like dry wood.

## II. Aluminous.

Aluminous Magnesia-Lime Amphibole. (a) Edenite. Color white to gray and pale-green, and also colorless; G. $=3 \cdot 0-3 \cdot 059$, Ramm. Resembles anthophyllite and tremolite. Named from the locality at Edenville, N. Y. (for analysis, see below.) To this variety belong various pale-colored amphiboles, haring less than five p. c. of oxide of iron.
(b) Smaragdite Saussure. A thin-foliated variety, of a light grass-green color, resembling much common green diallage. According to Boulanger it is an aluminous magnesia-lime amphibole, containing less than $3 \frac{1}{2}$ p. c. iron protoxide, and is hence related to edenite and the light green Pargas mineral. DesCloizeaux observes that it has the cleavage, and apparently the optical characters, of amphibole. H. $=5 ; \mathrm{G} .=3$. It forms, along with whitish or greenish saussurite, a rock.

Aluminous Magnesia-Lime-Iron Amphibole. (a) Pargastre; (b) Hornblende. Colors bright, dark, green, and bluish-green to grayish-black and black. $I \wedge I=124^{\circ} 1^{\prime}-124^{\circ} 25^{\prime}$; G. $=305-3.47$. Pargasite is usually made to include green and bluish-green kinds, occurring in stout lustrous crystals, or granular; and hornblende the greenish-black and black kinds, whether in stout crystals or long bladed, columnar, fibrous, or massive granular. But no line can be drawn between them. Pargasite occurs at Pargas, Finland, in bluish-green and grayish-black crystals.

Composition shown by the following analyses by Rammelsberg; (1) from Edenville; (\$) Wolfsburg, Bohemia ; (3) Brevig.

|  | $\mathrm{SiO}_{2}$ | $\mathrm{AlO}_{3}$ | $\mathrm{FeO}_{3}$ | FeO | MnO | Mgo | CaO | $\mathrm{Na}_{2} \mathrm{O}$ | $\mathrm{K}_{2} \mathrm{O}$ | $\mathrm{H}_{2} \mathrm{O}$ (ign) |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| (1) | 51.67 | 5.75 | $2 \cdot 86$ |  |  | $23 \cdot 37$ | $12 \cdot 42$ | 0.75 | 0.84 | $0 \cdot 46=98 \cdot 12$ |
| (2) | 41.98 | 14.31 | $5 \cdot 81$ | $7 \cdot 18$ |  | 14.06 | 12.55 | $1 \cdot 64$ | 1.54 | $0 \cdot 26=99 \cdot 10$ |
| (3) | 43 28 * | 6.31 | 6.62 | 21.72 | $1 \cdot 13$ | 3-62 | $9 \cdot 68$ | $3 \cdot 14$ | 2.65 | $0 \cdot 48=98 \cdot 63$ |

Pyr., etc.-The observations under pyroxene apply also to this species, it being impossible to distinguish the varieties by blowpipe characters alone.
Diff--Distinguished from pyroxene (and tourmaline) by its distinct prismatic cleavage, yielding an angle of $124^{\circ}$. Also in colored varieties by its dichroism, when examined in thin sections. Fibrous and columnar forms are much more common than with pyroxene, lamellar and foliated forms rare. Crystals often long, slender, or bladed. Differs from the fibrous zeolites in not gelatinizing with acids.

1somorphous and Dimorphous relations to Pyroxene.-The analogy in composition between pyroxene and hornblende has been abundantly illustrated. They have the same general formula; and under this formula there is but one difference of any importance, viz., that lime is a prominent ingredient in all the varieties of pyroxene, while it is wanting, or nearly so, in some of those of hornblende. The analogy between the two species in crystallization, or their essential isomorphism, was pointed out by G. Rose in 1831, who showed that the forms of both were referable to one and the same fundamental form. The prism $I$ of hornblende corresponds in angle to $i-2$ of pyroxene. Calculating from the angle $I \wedge I$ in pyroxene, $87^{\circ} 5^{\prime}$, the angle of $i-2$ is precisely $124^{\circ} 30^{\prime}$, or the angle $I \wedge I$ in hornblende. But while thus isomorphous in axial relations or form, they are also dimorphous. For (1) the cleavage in pyroxene is parallel to the prism of $87^{\circ} 5^{\prime}$, and in hornblende to that of $124 \frac{1}{2}^{\circ}$. (2) The occurring secondary planes of the latter are in general diverse from those of the former, so that the crystals differ strikingly in habit or system of modifications. Moreover, in pyroxene columnar and fine fibrous forms are uncommon; in hornblende, exceedingly common. (3) The several chemical compounds under pyroxene have one-tenth higher specific gravity than the corresponding ones under hornblende.

Vom Rath has described the occurrence of minute crystals of hornblende in parallel position upon crystals of pyroxene (Vesuvius), and in consequence of the relation between the two forms, thus brought out, suggests a change in the commonly accepted fundamental form of the latter. (Jahrb. Min., 1876.) This association of crystals of the two species in parallel position is not uncommon.
Obs.-Amphibole occurs in many crystalline limestones, and metamorphic granitic and schistose rocks, and sparingly in serpentine, and volcanic or igneous rocks. Tremolite, the magnesia-lime variety, is especially common in limestones, particularly magnesian or dolomitic ; actinolite, the magnesia-lime-iron variety, in steatitic rocks; and brown, dark-green, and black hornblende, in chlorite schists, mica schist, gneiss, and in various other rocks (syenyte, dioryte, etc.), of which it forms a constituent part. Asbestus is often found in connection with serpentine. Hornblende is often disseminated in black prismatic crystals through trachyte, and also through other igneous rocks, especially the feldspathic kinds.

Aussig and Teplitz in Bohemia, Tunaberg in Sweden, and Pargas in Finland, afford fine specimens of the dark-colored hornblendes. Actinolite in the Zillerthal; tremolite at St. Gothard, in granular limestone or dolomite; the Tyrol ; the Bannat, ets. Asbestus is found in Savoy, Salzburg, the Tyrol; in the island of Corsica. Some localities in the U. S. are :Carlisle, Pelham, etc., Muss., cummingtonite at Cummington. In C'onn., white crystals of tremolite in dolomite, Canaan. In N. York, Willsboro', St. Lawrence Co.; Warwick; with pyroxene at Edenvile; near Amity ; in Rossie; the variety pargasite in large white crystals at Diana, Lewis Co. In Penn., actinolite at Mineral Hill, in Delaware Co.; at Unionville. In Maryland, actinolite and asbestus at the Bare Hills; asbestus at Cooptown.

Hexagonite.-Described as a new mineral by Goldsmith, but shown by Kœnig to be only a variety of tremolite. From Edwards, St. Lawrence Co., N. Y.
ARFVEDSONITE.*-Near hornblende, but contains alkalies. Analysis, Ramm., Greenland. $\mathrm{SiO}_{2} 51 \cdot 22, \mathrm{AlO}_{3} \mathrm{tr} . . \mathrm{FeO}_{3} 23.75, \mathrm{FeO} 7 \cdot 80, \mathrm{MnO} 1 \cdot 12, \mathrm{CaO} 2 \cdot 08, \mathrm{MgO} 0.90, \mathrm{Na}_{2} \mathrm{O} 10.58$, $\mathrm{K}_{2} \mathrm{O} 0 \cdot 68$, ign $0 \cdot 16=98 \cdot 29$. Greenland; Brevig; Arendal.
Crocidolite.-Composition uncertain, near arfvedsonite. Analysis, Stromeyer, $\mathrm{SiO}_{2}$ $51 \cdot 22, \mathrm{FeO} 34 \cdot 08, \mathrm{MnO} 0 \cdot 10, \mathrm{MgO} 2 \cdot 48$, $\mathrm{CaO} 0 \cdot 03$, $\mathrm{Na}_{2} \mathrm{O} 7 \cdot 07$, H.O $4 \cdot 80=99 \cdot \% 8$. Fibrous, asbestus-like. Sometimes altered to "Faserquarz." Color lavender-blue or leek-green. Orange river, So. Africa. Vosges Mts.
Gastaldite.-Monoclinic. Cleavage prismatic, $I \wedge I=124^{\circ} 25^{\prime}$ (like amphibole). H. $=$ 6-7. G. $=3 \cdot 044$. Color dark-blue to azure-blue. Streak greenish-blue. Q. ratio $\mathrm{R}: \mathbb{R}: \mathrm{Si}$ $=1: 2 \cdot 6$; formula $\mathrm{R}_{3} \mathrm{Al}_{2} \mathrm{Si}_{3} \mathrm{O}_{27}$, with $\mathrm{R}=\mathrm{Fe}, \mathrm{Mg}, \mathrm{Ca} . \mathrm{Na}_{2}$. Analysis, Strüver, $\mathrm{SiO}_{2} 58 \cdot 55$, $\mathrm{AlO}_{3} 21 \cdot 40, \mathrm{FeO} 9.04, \mathrm{MgO} 3.92, \mathrm{CaO} 2.03, \mathrm{Na} \mathrm{O} 4.7 \% \mathrm{~K}_{2} \mathrm{O} \operatorname{tr}=99.71$. Occurs in chlorite elate in the valleys of Aosta and Looano.
Glatcophane.-Monoclinic. Cleavage prismatic, $1 \wedge I=124^{\circ} 51^{\prime}$, H. $=6.5$. G. $=3.0907$

Color blue, bluish-black. Q. ratio for bases to silicon 1:2. Analysis from Zermatt, by Bodewig, $\mathrm{SiO}_{2} 57 \cdot 81, \mathrm{AlO}_{3} 12 \cdot 03, \mathrm{FeO}_{3} 2 \cdot 17, \mathrm{FeO} 5 \cdot 78, \mathrm{MgO} 13.07, \mathrm{CaO} 2 \cdot 20, \mathrm{Na}_{2} \mathrm{O} 7 \cdot 33$ $=100.45$. Also from island of Syra.
Wichtisite, Finland.-Perhaps identical with glaucophane.

## BERYL.*

Hexagonal. $O \wedge 1=150^{\circ} 3^{\prime} ; \dot{c}=0.499$. Habit prismatic, the prism often vertically striated. Cleavage: basal imperfect; lateral indistinct. Occasionally coarse columnar and
large granular.
H. $=7 \cdot 5-8$.
G. $=2 \cdot 63-2 \cdot 76$.

Lustre vitreous, sometimes resinous. Color emerald-green, pale green, passing into light-blue, yellow, and white. Streak white. Transparent-subtranslucent. Fracture conchoidal, meven. Brittle. Double refraction feeble; axis negative.

Var.-This species is one of the few that


Haddam, Ct.


Siberia. occur only in crystals, and that have no essential variations in chemical composition. There are, however, two prominent groups dependent on color, the color varying as chrome or iron is present; but only the merest trace of either exists in any case. The crystals are usually oblong prisms. 1. Emerald. Color bright emerald-green, owing to the presence of chromium. Hardness a little less than for beryl, according to the lapidaries. 2. Beryl. Colors those of the species, excepting emerald-green, and due mainly to iron. The varieties of beryl depending on color are of importance in the arts, when the crystals are transparent enough to be of value as gems. The transparent bluish-green kinds are called aquamarine; also apple-green; greenish-yellow to iron-yellow and honey-yellow. Davidsonite is nothing but greenish-yellow beryl from near Aberdeen; and goshenite is a colorless or white variety from Goshen, Mass.

Comp. - Be $_{3} \mathrm{AlSi}_{6} \mathrm{O}_{18}=$ Silica $66 \cdot 8$, alumina $19 \cdot 1$, glucina $14 \cdot 1=100$.
Pyr., etc.-B.B. alone unchanged or becomes clouded; at a high temperature the edges are rounded, and ultimately a vesicular scoria is formed. Fusibility $=5^{\circ} \bar{\circ}$ (Kobell). Glass with borax clear and colorless for beryl, a fine green for emerald. Slowly soluble with salt of phosphorus without leaving a siliceous skeleton. A yellowish variety from Broddho and Finbo yields with soda traces of tin. Unacted upon by acids.

Diff.-Distinguished from apatite by its hardness, not being scratched by a knife, also harder than green tourmaline ; from chrysoberyl by its form, and from euclase and topaz by its imperfect cleavage; never massive.

Obs.-Emeralds occur in clay slate, in isolated crystals or in nests (not in veins), near Muso, etc., in N. Granada; in Siberia. Transparent beryls (aquamarines) are found in Siberia, Hindostan, and Brazil. Beautiful crystals also occur at Elba ; Ehrenfriedersdorf; Schlackenwald ; at St. Michael's Mount in Cornwall; Limoges in France; in Sweden; Fossum in Norway; and elsewhere.

Beryls of gigantic dimensions have been found in the United States, in N. Hamp., at Acworth and Grafton, and in Mass., at Royalston; but they are mostly poor in quality. A crystal from Grafton, according to Prof. Hubbard, measures 45 in. by 24 in its diameter, and a single foot in length by calculation weighs $1,076 \mathrm{lbs}$., making it, in all nearly 22 tons. Other localities are in Mass, at Barre; at Goshen; at Chesterfield. In Conn., at Haddam; Middletown; at Madison. In Penn., at Leiperville and Chester; at Mineral Hill.

Eudialyte.-Rhombohedral. Color rose-red. Exact composition uncertain. Analysis, Damour, $\mathrm{SiO}_{2} 50 \cdot 38, \mathrm{ZrO}_{2} 15 \cdot 60, \mathrm{Ta}_{2} \mathrm{O}_{0} 0.35, \mathrm{FeO} 6 \cdot 37, \mathrm{MnO} 1 \cdot 61, \mathrm{CaO} 9 \cdot 23, \mathrm{Na}_{2} \mathrm{O} 13 \cdot 10$, Cl $1.48, \mathrm{H}_{2} \mathrm{O} 1 \cdot 25=99.37$. West Greenland. Eucolite is similar, but contains also some of the cerium metals. Norway.
PoLLUCITE. $-3 \mathrm{R}_{3} \mathrm{~A}_{1} \mathrm{Ni}_{4} \mathrm{O}_{12}+2 \mathrm{aq}$ with $\mathrm{R}=$ mostly $\mathrm{Cs}(\mathrm{Na}, \mathrm{Li})$. If $\mathrm{Na}: \mathrm{Cs}=1: 2$, then $\mathrm{SiO}_{2} 42 \cdot 6, \mathrm{AlO}, 18 \cdot 2, \mathrm{Cs}_{2} \mathrm{O} 334, \mathrm{Na}_{2} \mathrm{O} 3 \cdot 7, \mathrm{H}_{2} \mathrm{O} 2 \cdot 1=100$. Isometric. Colorless. Island of Elba with castcrite.

## f. Unishicates. General Formiula $\mathrm{R}_{2} \mathrm{SiO}_{4}$.

 Chrysolite Group.CHRYSOLITE.* Olivine. Peridot.
Orthorhombic. $I \wedge I=94^{\circ} 2^{\prime} ; 0 \wedge 1-\bar{\imath}=128^{\circ} 28^{\prime}: c \cdot \bar{b}: \breve{a}:=1 \cdot 2588$ : $1 \cdot 0729: 1 . O \wedge 1-\tau=130^{\circ} 26 \frac{1^{\prime}}{}$. $\quad i \underline{2}$

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 $\wedge i-2$, ov. $i-\bar{i},=130^{\circ} 2^{\prime}$. Cleavage : $i-乞$ rather distinct. Massive and compact, or granular; usually in imbedded grains.
H. $=6-7 . \quad$ G. $=3 \cdot 33-3 \cdot 5$. Lustre vitreous. Color green-commonly olive-green, sometimes yellow, brownish, grayish-red, grayishgreen. Streak usually uncolored, rarely yellowish. Transparenttranslucent. Fracture conchoidal.

Comp., Var.- $\left(\mathrm{Mg}, \mathrm{Fe}_{2}\right)_{2} \mathrm{SiO}_{4}$, with traces at times of $\mathrm{Mn}, \mathrm{Ca}, \mathrm{Ni}$. The amount of iron varies much. If $\mathrm{Mg}: \mathrm{Fe}=12: 1$, the formula requires Silica $41 \cdot 39$, magnesia $50 \cdot 90$, iron protoxide $7 \cdot 71=100 ; \mathrm{Mg}: \mathrm{Fe}=9: 1,6: 1$, etc., and in hyalosiderite $2: 1$.

Pyr., etc.-B.B. whitens, but is infusible ; with the fluxes gives reactions for iron. Hyalosiderite and other varieties rich in iron fuse to a black magnetic globule. Some varieties give reactions for titanium and manganese. Decomposed by hydrochloric acid with separation of gelatinous silica.

Diff.-Distinguished by its infusibility. Commonly observed in small yellow imbedded grains.
Obs.-A common constituent of some eruptive rocks; and also occurring in or among metamorphic rocks, with talcose schist, hypersthene rocks, and serpentine ; or as a rock formation; also a constituent of many mettorites (e.g., the Pallas iron).

Occurs in eruptive rocks at Vesuvius, Sicily, Hecla, Sandwich Islands, and most volcanic islands or regions; in Auvergne; at Unkel, on the Rhine; at the Laacher See; in dolerite or basalt in Canada. Also in labradorite rocks in the White Mountains, N. H. (hyalosiderite) ; in Loudon Co., Va.; in Lancaster Co., Pa., at Wood's Mine.
The following are members of the Chrysolite Group:
Forsterite. $-\mathrm{Mg}_{2} \mathrm{SiO}_{4}$. Like chrysolite in physical characters. Vesuvius. Boltonite, essentially the same. Bolton, Mass.
Monticrllite, from Mt. Summa, and Batrachite, from the Tyrol, are (Ca, Mg) $)_{2} \mathrm{SiO}_{4}$, with $\mathrm{Ca}: \mathrm{Mg}=1: 1 . \quad \mathrm{H}=5-5 \%$. G. $=3 \cdot 03-3 \cdot 25$. Monticellite also occurs in large quantitien (v. Rath) on the Pesmeda Alp, Tyrol, altered to serpentine and fassaite.

Fayalite. $-\mathrm{Fe}_{2} \mathrm{SiO}_{4}, G=4-4 \cdot 14$. Color black. In volcanic rocks at Fayal, Azores; Mourne Mts., Ireland.
Hortonolite.- ( $\left.\mathrm{Fe}, \mathrm{Mg}_{2}\right)_{2} \mathrm{SiO}_{4}$, with $\mathrm{Fe}: \mathrm{Mg}=3: 2$. O'Neil mine, Orange Co., N. Y.
TEPIROTTE $-\mathrm{Mn}_{2} \mathrm{SiO}_{4}$. G. $=4-4 \cdot 12$. Color reddish-brown. Sterling Hill. N. J.; Sweden.
Roepperite. -An iron-manganese-zinc chrysolite. H. $=\overline{5} \cdot 5-6$. G. $=3 \cdot 95-4 \cdot 08$. Color dark-green to black. Stirling Hill, N. J.
Knebelite. $-(\mathrm{Fe}, \mathrm{Mn})_{2} \mathrm{SiO}_{4}$, with $\mathrm{Fe}: \mathrm{Mn}=1: 1$. $\quad \mathrm{G} .=4 \cdot 12$. Color gray. Dannemora.
Leucophanite.*-Composition given by the analysis (Ramm.) $\mathrm{SiO}_{2} 47.03$, $\mathrm{AlO}_{3} 1.03, \mathrm{Be} 0$ $10 \cdot 70, \mathrm{CaO} 23 \cdot 37, \mathrm{MgO} 0 \cdot 17, \mathrm{Na}_{2} \mathrm{O} 11 \cdot 26, \mathrm{~K}_{2} \mathrm{O} 0 \cdot 30, \mathrm{~F} 6 \cdot 57=100 \cdot 43$. Orthorhombic. G. $=$ 2.97. Color greenish-yellow. Occurs in syenite on the island of Lamoë, Norway.

Melipianite (Melinophan).-Composition given by the analysis (Ramm.) $\mathrm{SiO}_{2} 43.66$, $\mathrm{AlO}_{3}\left(\mathrm{FeO}_{3}\right) 1 \cdot 5 \cdot$, $\mathrm{BeO} 11 \cdot 74, \mathrm{CaO} 26.74, \mathrm{MgO} 0.11, \mathrm{Na}_{2} \mathrm{O} 8.55, \mathrm{~K}_{2} \mathrm{O} 1.40, \mathrm{H}_{2} \mathrm{O} 0.30$, F 5.73 $=99.80$. G. $=3.018$. Orthorhombic. Color yellow. Fredriksvärn, Norway.

Wöilerite.-Composition given hy the analysis (Ramm.) $\mathrm{SiO}_{2} 28 \cdot 43, \mathrm{Cb}_{2} \mathrm{O}_{5} 14.41, \mathrm{ZrO}_{4}$ $19 \cdot 63, \mathrm{CaO} 26 \cdot 18, \mathrm{FeO}(\mathrm{MnO}) 2 \cdot 50, \mathrm{Na}_{2} \mathrm{O} 7 \cdot 78=98 \cdot 93$. Monoclinic. G. $=3 \cdot 41$. Color lightyellow. Near Brevig, Norway.

## Willemite Group.

## WILLEMITE.

Rhombohedral. $R \wedge R=116^{\circ} 1^{\prime}, O \wedge I L=142^{\circ} 17^{\prime} ; c=067378$. Clear sge: $i$-2 easy in N. Jersey crystals; $O$ easy in those of Moresnet. Also massive and in disseminated grains. Sometimes fibrons.
$\mathrm{H} .=5 \cdot 5 . \quad \mathrm{G} .=3 \cdot 89-4 \cdot 18 ; 4 \cdot 27$, transparent crystals (Cornwall). Lustre vitreo-resinous, rather weak. Color whitish or greenish-yellow, when purest; apple-green, flesh-red, grayish-white, yellowish-brown ; often darkbrown when impure. Streak uncolored. Transparent to opaque. Brittle. Fracture conchoidal. Double .afraction strong; axis positive.

Var.-The crystals of Moresnet and New Jersey differ in occurring forms. The latter are often quite large, and pass under the name of troostite; they are commonly impure from the presence of manganese and iron.

Comp. $-\mathrm{Zn}_{2} \mathrm{SiO}_{4}=$ Silica $27 \cdot 1$, zinc oxide $72 \cdot 9=100$.
Pyr., etc.-B.B. in the forceps glows and fuses with difficulty to
 a white enamel; the varieties from New Jersey fuse from 3.5 to 4. The powdered mineral on charcoal in R.F. gives a coating yellow while hot and white on cooling, which, moistened with solution of cobalt, and treated in 0. F., is colored bright green. With soda the coating is more readily obtained. Decomposed by hydrochloric acid with separation of gelatinous silica.

Obs.-From Vieille-Montagne near Moresnet; also at Stolberg ; at Raibel in Carinthia; at Kucsaina in Servia, and in Greenland. In New Jersey, at both Franklin and Stirling in such quantity as to constitute an important ore of zinc. It occurs intimately mixed with zincite and franklinite, and is found massive of a great variety of colors, from pale honeyyellow and light green to daris ash-gray and flesh-red ; sometimes in crystals (troostite).

## DIOPTASE. Emerald-Copper.

Rhombohedral; tetartohedral. $R \wedge R=126^{\circ} 24^{\prime} ; O \wedge R=148^{\circ} 38^{\prime}$; $\dot{c}=0.5281$. Cleavage: $R$ perfect. Twins: twinningplane $R$. Also massive.
$\mathrm{H} .=5$. G. $=3 \cdot 278-3 \cdot 348$. Lustre vitreous. Color emerald-green. Streak green. Transparent-subtranslucent. Fracture conchoidal, uneven. Brittle. Double refraction strong, positive.

Comp.-Q. ratio for $\mathrm{Cu}: \mathrm{Si}: \mathrm{H}=1: 2: 1$; formula $\mathrm{H}_{2} \mathrm{CuSiO}_{4}$ (Ramm.) = Silica $38 \cdot 1$, copper oxide $50 \cdot 4$, water $11 \cdot 5=100$.

Pyr., etc.-In the closed tube blackens and yields water. B.B. decrepitates, colors tne flame emerald-green, but is infusible. With the fluxes gives the reactions for copper. With soda on charcoal a giobule of metallic copper. Decomposed by acids with gelatinization.

Obs.-Dioptase occurs disposed in well-defined crystals and amorphous on quartz, occupying seams in a conupact limestone west of the hill of Altyn-Tubeh in the Kirghese Steppes; also in the Siberian
 gold-washings. From Chase Creek, near Clifton, Arizona, in fine crystals, on a " mahngany ore," consisting of limonite and copper oxide.

Phenacite.- $\mathrm{Be}_{2} \mathrm{SiO}_{4}$. Rhombohedral. Colorless. Resembles quartz. Takovaja; Miask; Durango, Mexico.

Friedelite. - Rhombohedral. $0 \wedge R=147^{\circ} ; \quad R \wedge R=123^{\circ}$ 42'. Cleavage: 0 easy. H. $=4.75$. G. $=3.07$. Also massive, saccharoidal. Color rose-red. Translucent. Double refraction strong, axis negative. Analysis, $\mathrm{SiO}_{2} 36.12, \mathrm{MnO}(\mathrm{FeO} \operatorname{tr}) 53.05, \mathrm{MgO}, \mathrm{CaO} 2.96$, $\mathrm{H}_{2} \mathrm{O} 7 \cdot 87=100$ This corresponds to the formula $\mathrm{Mn}_{4} \mathrm{Si}_{3} \mathrm{O}_{10}+2 \mathrm{H}_{2} \mathrm{O}$. If the water is basic as in dioptase, with which it seems to be related in form, the formula is $\mathrm{H}_{4} \mathrm{Mn}_{4} \mathrm{Si}_{3} \mathrm{O}_{15}=$ $\mathrm{I}_{2} \mathrm{SiO}_{4}$. This requires $\mathrm{SiO}_{2} 36 \cdot 00, \mathrm{MnO} 56 \cdot 80, \mathrm{H}_{2} \mathrm{O} 7 \cdot 20=100$. Occurs with diallogite and alabandite at the manganese mine of Adervielle, Hautes-Pyrénées. (Bertrand, C. R., May, 1876.)

## HELVITE.*

Isometric: tetrahedral. Cleavage : octahedral, in traces.
$\mathrm{H} .=6-6 \cdot 5$. G. $=3 \cdot 1-3 \cdot 3$. Lustre vitreous, inclining to resinous. Color honey-yellow, inclining to yellowish-brown, and siskin-green. Streak uncolored. Subtranslucent. Fracture uneven.

Comp.-Q. ratio for $\mathrm{R}: \mathrm{Si}=1: 2$; for $\mathrm{Mn}+\mathrm{Fe}: \mathrm{Be}=1: 1$; formula $3\left(\mathrm{Be}, \mathrm{Mn}, \mathrm{Fe}_{2} \mathrm{SiO}_{4}+\right.$ (Mn.Fe)S (Ramm.). Analysis by Teich, Lupikko, Finland, $\mathrm{SiO}_{2} 30 \div 31, \mathrm{BeO} 10.51, \mathrm{MnO}$ $37 \cdot 87$, $\mathrm{FeO} 10 \cdot 37$, CaO $4 \cdot 72$, ign $0 \cdot 22$, S $5 \cdot 95=99 \cdot 95$.

Pyr., etc.-Fuses at 3 in R.F. with intumescence to a yellowish-brown opaque bead, becoming darker in R.F. With the fluxes gives the manganese reaction. Decomposed by hydrochloric acid, with evolution of sulphuretted hydrogen, and separation of gelatinous silica.

Obs.-Occurs in gneiss at Schwarzenberg in Saxony ; at Breitenbrunn. Saxony; at Hortekulle near Modum, and also at Brevig in Norway, in zircon-syenite.

## DANALITE.*

Isometric. In octahedrons, with planes of the dodecahedron; the dodecahedral faces striated parallel to the longer diagonal.
$\mathrm{H} .=5 \cdot 5-6$. G. $=3 \cdot 427$. Lustre vitreo-resinous. Color flesh-red to gray. Streak similar, but lighter. Translucent. Fracture subconchoidal, uneven. Brittle.

Comp. $-3(\mathrm{Be}, \mathrm{Fe}, \mathrm{Mn}, \mathrm{Zn})_{2} \mathrm{SiO}_{4}+(\mathrm{Fe}, \mathrm{Mn}, \mathrm{Zn}) \mathrm{S}$. Analysis : J. P. Cooke, Rockport, $\mathrm{SiO}_{2}$ 81.73, $\mathrm{FeO} 27 \cdot 40, \mathrm{MnO} 6 \cdot 28$, $\mathrm{ZnO} 17 \cdot 51$, BeO $13 \cdot 83$, $\mathrm{S} 5 \cdot 48=102 \cdot 23$. By subtracting from the analysis oxygen $2 \cdot 74$, equivalent to the sulphur, the sum is $99 \cdot 49$.

Pyr., etc.-B.B. fuses readily on the edges to a black enamel. With soda on charcoal gives a slight coating of zinc oxide. Perfectly decomposed by hydrochloric acid, with evolution of sulphuretted hydrogen and separation of gelatinous silica.
Obs.-Occurs in the Rockport granite, Cape Ann, Mass., small grains being disseminated through this rock; also near Gloucester, Mass.

Eulypite (Kieselwisnuth, Germ.).-Isometric, tetrahedral; in minute crystals often aggregated together. $\mathrm{H} .=4 \cdot 5-5$. G. $=6 \cdot 106$. Color grayish-white to brown. C'omp. A unisilicate of bismuth, $\mathrm{Bi}_{4} \mathrm{Si}_{3} \mathrm{O}_{12}$. Schneeberg. Agricolite. Composition similar, but form monoclinic. Occurs in globular masses having a radiated structure, and in indistinct groups of crystals. Schneeberg (color hair-brown) and Johanngeorgenstadt (color wine-yellow).

BIsMUTOFERRITE.-Cryptocrystalline; generally massive. H. $=3.5$. G. $=4 \cdot 47$. Color vlive-green. Analysis (Frenzel) $\mathrm{SiO}_{2} 24 \cdot 05, \mathrm{feO}_{3} 33 \cdot 12, \mathrm{Bi}_{2} \mathrm{O}_{3} 42 \cdot 83=100$. Schneeberg. Eypochlorite is hornstone mixed with the above mineral and other impurities.

## Garnet Group.

GARNET.* Granat, Germ.
Isometric; dodecahedron, f. 537, and the trapezohedron 2-2, f. 538, the most common forms; octahedral form very rare. Distorted forms
shown in f. 345-352, pp. 105, 106. Cleavage : dodecahedral, sometimes quite distinct. Twins: twinning-plane octahedral. Also massive; granular, coarse, or fine, and sometimes friable; lamellar, lamellæ thick and bent. Also very compact, crypto-crystalline like saussurite.

$H .=6 \cdot 5-7 \cdot 5 . \quad$ G. $=3 \cdot 15-4.3$. Lustre vitreous-resinous. Color red, brown, yellow, white, apple-green, black; some red and green colors often bright. Streak white. Transparent-subtranslucent. Fracture subconchoidal, uneven. Brittle, and sometimes friable when granular massive; very tough when compact eryptocrystalline. Sometimes doubly refracting in consequence of lamellar structure, or in some cases from alteration.

Comp., Var.-Garnet is a unisilicate of elements in the sesquioxide and protoxide statces, having the general formula $\mathrm{R}_{3} \mathrm{RSi}_{3} \mathrm{O}_{12}$. There are three prominent groups, based on the nature of the predominating sesquioxide.
I. Alumina gabnet, in which aluminum (Al) predominates.
II. Iron garnet, in which iron ( Fe ) predominates, usually with some aluminum.
iII. Chrome garnet in which chromium ( E r) is most prominent.

There are the following varieties or subspecies, based on the predominance of one or another of the protoxides:
A. Grossularite, or Lime-Alumina garnet. B. Pyrope, or Magnesia-Alumina garnet. C. almandite, or Iron-Alumina garnet. D. Spessartite, or Mangunese-Alumina garnet.
E. Andradite, or Lime-Iron garnet, including 1, ordinary; 2, manganesian, or lothoffite; 3, yttriferous, or Ytter-garnet. F. Bredbergite, or Lime-Magnesia-Iron gavnet. G. ouvaiovite, or Lime-Chrome garnet. Excepting the last, these subdivisions blend with one another more or less completely.
A. Lime-Alumina garnet; Grossularite. Cinnamon stone. A silicate mainly of aluminum and calcium ; formula mostly $\mathrm{Ca}_{3} \mathrm{AlSi}_{3} \mathrm{O}_{12}=$ Silica $40 \cdot 0$, alumina $22 \cdot 8$, lime $37 \cdot 2=100$. But some calcium often replaced by iron, and thus graduating toward the Almandite group. Color (a) white; (b) pale green; (c) amber- and honey-yellow; (d) wine-yellow, brownish-yellow, cinnamon-brown; rarely (e) emerald-green from the presence of chromium. G. $=3 \cdot 4-3 \cdot 75$.
B. Mrgnesia-Alumina garnet; Prrope. A silicate of aluminum, with various protoxide bases, anong which magnesium predominates much in atomic proportions, while in small proportion in other garnets, or absent. Formula ( $\mathrm{Mg}, \mathrm{Ca}, \mathrm{Fe}, \mathrm{Mn})_{3},+1 \mathrm{Si}_{3} \mathrm{O}_{12}$. The original pyrope is the kind containing chromium. In the analysis of the Arendal magnesia-garnet, $\mathrm{Mg}: \mathrm{Ca}^{2}$ : $\mathrm{Fe}+\mathrm{Mn}=3: 1: 2 ; \mathrm{SiO}_{2} 42 \cdot 45, \mathrm{AlO}_{3} 22 \cdot 47$, $\mathrm{FeO} 9 \cdot 29, \mathrm{MnO} 6 \cdot 27$, $\mathrm{MgO} 13 \cdot 43$, $\mathrm{CaO} \mathrm{Cl}_{6} \cdot n 3=$ 100.44 Wacht. G. $=3 \cdot 15 \%$. The name pyrope is from $\pi v_{i} \omega \omega \pi \delta^{\prime}$, firc-like.
C. Iron-Alumina garnet; Almandite. A silicate mainly of alumizum and iron ( Fe ); formula $\mathrm{Fe}_{3}+1 \mathrm{Si}_{3} \mathrm{O}_{12}=$ Silica $36 \cdot 1$, alumina $20 \cdot 6$, iron protoxide $4: 3 \cdot 3=100$; or Mn may replace some of the Fe , and $\mp \mathrm{F}$ part of the Al . Color fine deep-red and transparent, and then called precious garnet; also brownish-red and translucent or subtranslucent, common garnet; black, and then referred to var. melanite. Part of common garnet belongs to the Andradits group, or is iron garnet.
D. Manganese-Alumina garnet; Spessartite. Color dark hyacinth-red (fr. Spessurt), sometimes with a shade of violet, to brownish-red. G. $=3 \cdot 7-4 \cdot 4$. Analysis, Haddam, Ct.s $\mathrm{SiO}_{2} 36 \cdot 16, \mathrm{Al}_{2} \mathrm{O}_{3} 19 \cdot 76$, $\mathrm{FeO} 11 \cdot 10, \mathrm{MnO} 32 \cdot 18$, $\mathrm{MgO} 0 \cdot 22, \mathrm{CaO} 0 \cdot 58=100$, Ramm.
E. Lime-Iron garnet ; Andradite. Aplome. Color various, including wine-, topaz-, and greenish-yellow (topazolite), apple-green, brownish-red, brownish-yellow, grayish-green, dark green, brown, grayish-black, black. G. $=3.64-4$.

Comp.- $\mathrm{Ca}_{3} \mathrm{FeSi}_{3} \mathrm{O}_{12}$, this includes: (a) Topazoite, having the color and transparency of topaz, and also sometimes green; although resembling essonite, Damour has shown that it belongs here. (b) Colophonite, a coarse granular kind, brownish-yellow to dark reddishgrown in color, resinous in lustre, and usually with iridescent hues; named after the resin oolophony. (c) Melanite (named from $\mu \dot{k} \lambda a s$, black), black, either dull or lustrous; but all black garnet is not here included. Pyreneite is grayish-black melanite; the original afforded Vauquelin 4 p. c. of water, and was iridescent, indicating incipient alteration. (d) Dark green garnet, not distinguishable from some allochroite, except by chemical means.
F. Lime-Magnesia Iron garnet; Bredbergite. A variety from Sala, Sweden, is here included. Formula $(\mathrm{Ca}, \mathrm{Mg})_{3} \mathrm{FeSi}_{3} \mathrm{O}_{12}=$ Silica $37 \cdot 2$, iron sesquioxide $33 \cdot 1$, magnesia $12 \cdot 4$, lime $17 \cdot 3=100$. It corresponds under Iron garnet nearly to aplome under Alumina garnet.
G. Lime-Chrome garnet; Ouvarovite. A silicate of calcium and chronium. Formula $\mathrm{Ca}_{8} \mathrm{ErSi}_{3} \mathrm{O}_{12}$. In the Ural variety, a fourth of the chromium oxide is replaced by aluminum oxide; that is, $\mathrm{Al}: \mathrm{Cr}=1: 3$ nearly. Color emerald-green. $\mathrm{H}=7 \cdot 5$. G. $=3 \cdot 41-3 \cdot \mathrm{j} 2$. B.B. infusible; with borax a clear chrome-green glass. Named after the Russian minister, Uvarof.

Pyr., etc.-Most varieties fuse easily to a light-brown or black glass; F. $=3$ in almandite, spessartite, grossularite, and allochroite ; 3.5 in pyrope; but ouvarovite is almost infusible, F. $=6$. Allochroite and almandite fuse to a magnetic globule. Reactions with the fluxes vary with the bases. Almost all kinds react for iron ; strong manganese reaction in spessartite, and less marked in other varieties; a chromium reaction in ouvarovite, and in most pyrope. Some varieties are partially decomposed by acids; all except ouvarovite are decomposed after ignition by hydrochloric acid, and generally with separation of gelatinous silica. Decomposed on fusion with alkaline carbonates.

Diff.-Ordinary garnets are distinguished fromzircon by their fusibility B. B., but they fuse less readily than vesuvianite ; the vitreous lustre, absence of pismatic structure, and usually the form, are characteristic; it has a higher specific gravity tl an tourmaline.

Obs.-Garnet crystals are very common in mica schist, gnciss, syenitic gneiss, and hornblende and chlorite schist; they occur often, also, in granite, syenite, crystalline limestones, sometimes in serpentine, and occasionally in trap and volcanic tufa and lava.

Some localities are: Cinnamon-stone (Exsonite), Ceylon; Mussa-Alp in Piedmont. Grossularite, Siberia; Tellemark, Norway; Ural. Almandite, Ceylon, Pegu, Brazil, and Greenland. Common garnet in large dodecahedrons, Sweden; Arendal and Kongsberg in Norway, and the Zillerthal. Melanite at Vesuvius and in the Hautes-Pyrénées (Pyreneite). Aplome at Schwarzenberg in Saxony. Spessartite at Spessart in Bavaria, Elba, at St. Marcel, Piedmont. l'yrope in Bohemia, also at Zöblitz in Saxony. Ouvarovite in the Urals.

In N. America in Maine. Phippsburg, Rumford, Windham, at Brunswick, etc. In N. Hamp., Warren. In Mass., at Carlisle; massive at Newbury ; at Chesterfield. In Conn., trapezohedrons, $\frac{1}{2}-1 \mathrm{in}$., in mica slate, at Reading and Monroe ; Haddam. In N. York, at Roger's Rock; Crown l'oint, Essex Co.; at Amity. In N. Jersey, at Franklin. In Penn., in Chester Co., at Pennsbury; near Knauertown, at Keims' mine ; at Chester, brown; in Leiperville, red; near Wilmington. In California, in Los Angeles Co., in Mt. Meadows; ouvarovite at New Idria; pyrope, near Santa Fé, New Mexico. In Canada, at Marmora, at Grenville; chrome-garnet in Orford, Canada.

The cinnamon-stone from Ceylon (called hyacinth) and the precious garnet are used as gems when large, finely colored, and transparent. - The stone is cut quite thin, on account of the depth of color, with a pavilion cut below, and a broad table above bordered with small facets. An octagonal garnet measuring $8 \frac{1}{2}$ lines by $6 \frac{1}{2}$ has sold for near $\$ 700$. Pulverized garnet is sometimes employed as a substitute for emery.
$\mathrm{H} .=7 \cdot 5 . \mathrm{G} \cdot=4 \cdot 05-4 \cdot 75$. Lustre adamantine. Colorless, pale yellowish, grayish, yellowish-green, brownish-yellow, reddish-brown. Streak un colored. Transparent to subtranslucent and opaque. Fracture conchoidal brilliant. Donble refraction strong, positive.


Var.-The colorless and yellowish or smoky zircons of Ceylon have there been long called jargons in jewelry, in allusion to the fact that, while resembling the diamond in lustre, they were comparatively worthless; and thence came the name zircon. The brownish, orange, and reddish kinds were called distinctively hyacinths-a name applied also in jewelry to some toprz and light-colored garnet.

Comp. $-\mathrm{ZrSiO}_{4}=$ Silica 33, zirconia $67=100$. Klaproth discovered the earth zirconia in this species in 1789.

Pyr., etc.-Infusible; the colorless varieties are unaltered, the red become colorless, while dark-colored varieties are made white; some varieties glow and increase in density by ignition. Not perceptibly acted upon by salt of phosphorus. In powder is decomposed when fused with soda on the platinum wire, and if the product is dissolved in dilute hydrochlorio acid it gives the orange color characteristic of zirconia when tested with turmeric paper. Not acted upon by acids except in fine powder with concentrated sulphuric acid. Decomposed by fusion with alkaline carbonates and bisulphates.

Diff.-Distinguished by its adamantine lustre, hardness, and infusibility; the occurrence of square prismatic forms is also characteristic.

Obs.-Occurs in crystalline rocks, especially granular limestone, chloritic and other schists ; gneiss, syenite ; also in granite; sometimes in iron-ore beds.

Found in alluvial sands in Ceylon ; in the gold regions of the Ural; at Arendal in Norway; at Fredericksvärn, in zircon-syenite; in Transylvania; at Bilin in Bohemia.

In N. America, in N. York, at Moriah, Essex Co., and in Orange Co.; in Warwick; near Amity; at Diana in Lewis Co.; also at Rossie. In N. Jersey, at Franklin; at Trenton in gneiss. In N. Car., in Buncombe Co.; in the sands of the gold washings of McDowell Co. In California, in the auriferous gravel of the north fork of the American river, and elsewhere. In Canada, at Grenville, etc.

## VESUVIANITE.* Idocrase.

'Tetragonal. $0 \wedge 1-i=151^{\circ} 45^{\prime} ; \dot{c}=0.537199$ (v. Kokscharof). $0 \wedge 1$ $=142^{\circ} 46 \frac{1^{\prime}}{} 1 \wedge 1$, ov. $1-i,=129^{\circ} 21^{\prime}$. Cleavage: $I$ not very distinct, $O$ still less so. Columnar structure rare, straight and divergent, or irregular. Sometimes granular massive. Prisms usually terminating in the basal plane $O$; rarely in a pyramid or zirconoid; sometimes the prism nearly wanting, and the form short pyramidal with truncated summit and edges.
II. $=6.5$. G. $=3.349-3.45$. Lustre vitreous; often inclining to re-
 inoms. Color brown to green, and the latter frequently bright and clear; occasionally sulphuryellow, and also pale blue ; sometimes green along the axis, and pistachio-green transversely. Streak white. Subtransparentfaintly subtranslucent. Fracture subconchoidal-meven. Double refraction feeble, axis negative.

Comp., Var.-Q. ratio for $\mathrm{R}: \mathrm{R}: \mathrm{Si}=$ 4:3:7 (according to the latest investigations of Rammelsberg). $\mathrm{R}=\mathrm{Ca}$ (also $\mathrm{Mg}, \mathrm{Fe}$, or $\left.\mathrm{H}_{2}, \mathrm{~K}_{2}, \mathrm{Na}_{2}\right) ; \mathrm{H}=\mathrm{Al}$ and also Fe . If we neglect the water the empirical formula is $\mathrm{R}_{8} \mathrm{R}_{2} \mathrm{Si}_{7} \mathrm{O}_{28}$, where the quantivalent ratio of bases to silicon is $1: 1$. The ratio of $\mathbf{R}: \mathrm{lf}$ varies much, which, as stated by Rammelsberg is the explanation of the different varieties. Analyses by Rammelsberg. (1) Monzoni ; (2) Wilui, Siberia.

|  | $\mathrm{SiO}_{2}$ | $\mathrm{AlO}_{3}$ | $\mathrm{FeO}_{3}$ | FeO | MgO | CaO | $\mathrm{Na}_{2} \mathrm{O}\left(\mathrm{K}_{2} \mathrm{O}\right)$ | $\mathrm{H}_{2} \mathrm{O}$ |
| :--- | :--- | :--- | :--- | :--- | :---: | :--- | :--- | :--- |
| (1) | 37.32 | 16.08 | 3.75 | 2.91 | 2.11 | 35.34 | 016 | $2.08=99.75$ |
| (2) | 38.40 | 13.72 | 5.54 | - | 6.88 | 35.04 | 0.66 | $0.82=101.06$. |

Pyr., etc.-B.B. fuses at 3 with intumescence to a greenish or brownish glass. Magnus states that the density after fusion is 2.93-2.945. With the fluxes gives reactions for iron, and a variety from St. Marcel gives a strong manganese reaction. Cyprine gives a reaction for copper with salt of phosphorus. Partially decomposed by hydrochloric acid, and completely when the mineral has been previously ignited.

Diff.-Resembles some brown varieties of garnet, tourmaline, and epidote, but its tetragonal form and easy fusibility distinguish it.

Obs.-Vesuvianite was first found among the ancient ejections of Vesuvius and the dolomitic blocks of Somma. It has since been met with most abundantly in granular limestone ; also in serpentine, chlorite schist, gneiss, and related rocks. It is often associated with limegarnet and pyroxene. It has been observed imbedded in opal.

Occurs at Vesuvius ; at Ala, in Piedmont ; at Monzoni in the Fassathal ; near Christiansand, Norway ; on the Wilui river, near L. Baikal; in the Urals, and elsewhere.

In N. America, in Maine, at Phippsburg and Rumford, abundant; Sandford (f. 551). In $N$. York, at Amity. In N. Jersey, at Newton. In Canada, at Calumet Falls; at Grenville.

Melilite from Capo di Bove, and Humboldtilite from Mt. Somma, are similar in composition. Analysis of the melilite by Damour. $\mathrm{SiO}_{2} 38 \cdot 34, \mathrm{AlO}_{3} 8 \cdot 61, \mathrm{FeO}_{3} 10 \cdot 02, \mathrm{CaO} 32 \cdot 05$, MgO 6.71, $\mathrm{Na}_{2} \mathrm{O} 2 \cdot 12, \mathrm{~K}_{2} \mathrm{O} 1 \cdot 51=99 \cdot 36$. Tetragonal. Color honey-yellow.

## Epidote Group.

The species of the Epidote Group are characterized by high specific gravity, above 3 ; hardness above $\check{5}$; fusibility B.B. below 4 ; anisometric crystallization, and therefore biaxial polarization ; the dominant prismatic angle $112^{\circ}$ to $117^{\circ}$; fibrous forms, when they occur, always brittle; colors white, gray, brown, yellowish-green. and deep green to black, and sometimes reddish.

The prismatic angle in zoisite and other orthorhombic species is $I \wedge I$; but in epidote it is the angle over a horizontal edge between the planes $O$ and $i-i$, the orthodiagonal of epidote corresponding to the vertical axis of zoisite, as explained under the latter species.

## EPIDOTE. Pistazite.

Monoclinic. $C^{\gamma}=89^{\circ} 27^{\prime} ; i-2 \wedge i-2=63^{\circ} 8^{\prime}, 0 \wedge 1-i=122^{\circ} 23^{\prime} ; c: b: a$ $=0.43436: 0 \cdot 30719: 1$. () $\wedge 1-i=154^{\circ} 3^{\prime}, U \wedge-1-i=154^{\circ} 15^{\prime}, i-i \wedge-1$ $=104^{\circ} 48^{\prime}, i-i \wedge 1=104^{\circ} 15^{\prime}$. Crystals nsually lengthened in the direction of the orthodiagonal, or parallel to $i-i$; sometimes long acicular. Cleavage: $i-i$ perfect; $1-i$ less so. Twins: twinning-plane $1-i$; also $i-i$. Also fibrous, divergent, or parallel ; also granular, particles of various sizes. sometimes fine granular, and forming rock-masses.

$\mathrm{H}=6-7$. G. $=3 \cdot 25-3 \cdot 5$. Lustre vitreons, on $i-i$ inclining to pearly or resinons. Color pistachio-green or yellowish-green to brownish-green, greenish-black, and black; sometimes clear red and yellow; also gray and grayish-white. Pleochroism often distinct, the crystals being usually least yellow in a direction through $1-i$ (see p. 166). Streak uncolored, grayish. Subtransparent-opaque; generally subtranslucent. Fracture uneven. Brittle.

Var.-Epidote has ordinarily a peculiar yellowish-green (pistachio) color, seldom found in other minerals. But this color passes into dark and light shades-black on one side, and brown on the other. Most of the brown and nearly all the gray epidote belongs to the speaies Zoisite; and the reddish-brown or reddish-black, containing much oxide of manganese, to the species Piedmontite, or Manganepidot; while the black is mainly of the species Allanite, or Cerium-epidote.

Comp.-Quantivalent ratio for $\mathrm{Ca}: \mathrm{R}: \mathrm{Si}=4: 9: 12$, and $\mathrm{H}: \mathrm{Ca}=1: 4$. The formula is then $\mathrm{H}_{2} \mathrm{Ca}_{4} \mathrm{H}_{3} \mathrm{Si}_{6} \mathrm{O}_{20^{\circ}} \quad \mathrm{Z}$ is Fe or A11, the ratio varying from 1:2 to $1: 6$. Analysis, Untersulzbach, Tyrol, by Ludwig: $\mathrm{SiO}_{2} 37 \cdot 83, \mathrm{AlO}_{3} 22 \cdot 63, \mathrm{FeO}_{3} 15 \cdot 05, \mathrm{FeO} 0 \cdot 93, \mathrm{CaO} 23 \cdot 27, \mathrm{H}_{.2} \mathrm{O}$ $2 \cdot 0 \overline{=}=100.76$. As first shown by Ludwig, epidote contains about 2 p. c. water, which is given off only at high temperatures.

Pyr., etc.-In the closed tube gives water at a high temperature. B.B. fuses with intumescence at $3-35$ to a dark brown or black mass which is generally magnetic. Reacts for iron and sometimes for manganese with the fluxes. Partially decomposed by hydrochloric acid, but when previously ignited, gelatinizes with acid. Decomposed on fusion with alkaline carbonates.

Diff.-Distinguished often by its peculiar yellowish-green color ; yields a magnetic globule, B. B. Prismatic forms often longitudinally striated, but they have not the angle, cleavage, or brittleness of tremolite.

Obs.-Epidote is common in many crystalline rocks, as syenite, gneiss, mica schist, hornblendic schist, serpentine, and especially those that contain the ferriferous mineral hornblende. It often accompanies beds of magnetite or hematite in such rocks. It is sometimes found in geodes in trap; and also in sandstone adjoining trap dikes, where it has been formed by metamorphism through the heat of the trap at the time of its ejection. It also occurs at times in nodules in different quartz-rocks or altered sandstones. It is associated often with quartz, pyroxene, feldspar, axinite, chlorite, etc., in the Piedmontese Alps.

Beautiful crystallizations come from Bourg d'Oisans, Ala, and Traversella, in Piedmont, Zermatt and elsewhere in Switzerland; Monzoni in the Fassathal ; the Untersulzbachthal and. Zillerthal in the Tyrol.

In N. America, occurs in Mass., at Chester ; at Athol ; at Rome. In Conn., at Handam.

In N. York, at Amity ; near Monroe. Orange Co.; at Warwick. In N. Jersey, at Frankin In Penn., at E. Bradford. In Michigan, in the Lake Superior region. In Canada, at St Joseph.

Piedmontite (Manganepidot, Germ.).-A manganese epidote; formula, $\mathrm{H}_{2} \mathrm{Ca}_{4} \mathrm{R}_{3} \mathrm{Si}_{6} \mathrm{O}_{2 \mathrm{O}_{4}}$ with f principally Afn (also $\mathrm{Al}, \mathrm{Fe}$ ). Color reddish-brown. St. Marcel, Aosta valley, Pied. mont.

## ALLANITE.

Monoclinic, isomorphous with epidote. $C=89^{\circ} 1^{\prime} ; O \wedge 1-i=122^{\circ} 50 \frac{1}{2}^{\prime}$, $i-2 \wedge i-2=63^{\circ} 58^{\prime} ; \dot{c}: b: \grave{a}=$

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 $0 \cdot 483755: 0 \cdot 312187: 1$. Crystals either short, flat tabular, or long and slender, sometimes acicular. Twins like those of epidote. Cleavage: $i-i$ in traces. Also massive, and in angular or rounded grains.
$\mathrm{H} .=5 \cdot 5-6 . \quad \mathrm{G} .=3 \cdot 0-4 \cdot 2$. Lustre subunetallic, pitchy, or resinonsoccasionally vitreous. Color pitchbrown to black, either brownish, greenish, grayish, or yellowish. Streak gray, sometimes slightly greenish or brownish. Subtranslucent-opaque. Fracture uneven or subconchoidal. Brittle. Donble refraction either distinct, or wanting.

Var.-Allanite (Cerine). In tabular crystals or plates. Color black or brownish-black. $\mathbf{G}_{\text {. }}=3.50-3.95$; found among specimens from East Greenland, brought to Scotland by C. Giesecké. Bucklandite is anhydrous allanite in small black crystals from a mine of magnetite near Arendal, Norway. Referred here by v. Rath on the ground of the angles and physical characters.

Orthite. Including, in its original use, the slender or acicular prismatic crystals, often a foot long, containing some water. But these graduate into massive forms, and some orthites are anhydrous, or as nearly so as much of the allanite. The name is from ojp日bs, straight. The tendency to alteration and hydration may be due to the slenderuess of the crystals, and the consequent great exposure to the action of moisture and the atmosphere. H. $=5-6$. G. $=2 \cdot 80-3 \cdot 75$. Lustre vitreous to greasy.

Comp.-Not altogether certain, as analyses vary considerably, some showing the presence of considerable water. According to Rammelsberg the Q. ratio for bases to silicon=1:1 (epidote $=1 \frac{1}{6}: 1$ ). Allanite has then the garnet formula, $\mathrm{R}_{3} \mathrm{Z} \mathrm{Si}_{3} \mathrm{O}_{12}$, where $\mathrm{R}=\mathrm{Ce}(\mathrm{La}, \mathrm{Di})$, $\mathrm{Fe}(\mathrm{Mn}), \mathrm{Ca}(\mathrm{Mg})$, and occasionally $\mathrm{Y}, \mathrm{Na}_{2}, \mathrm{~K}_{2}$, etc.; $\mathrm{P}=\mathrm{Al}$ or Fe . Analysis, allanite ( Ramm .), Fredrikshaab, $\mathrm{SiO}_{2} 33 \cdot 78, \mathrm{AlO}_{3} 14 \cdot 03, \mathrm{FeO}_{3} 6 \cdot 36, \mathrm{FeO} 13 \cdot 63, \mathrm{CeO} 12 \cdot 63, \mathrm{LaO}(\mathrm{DiO}) 5 \cdot 67, \mathrm{CaO}$ $12 \cdot 12, \mathrm{H}_{2} \mathrm{O} 1 \cdot 78=100$.

Pyr., etc.-Some varieties give water in the closed tube. B.B. fuses easily and swells up $(\mathbf{F} .=2.5)$ to a dark, blebby, magnetic glass. With the fluxes reacts for iron. Most varietifs galatinize with hydrochloric acid, but if previously ignited are not decomposed by acid.

Obs.-Occurs in albitic and common feldspathic granite, syenite, zircon-syenite, porphyry, White limestone, and often in mines of magnetic iron. Allanite occurs in Greenland; at Criffel in Scot.and; at Jotun Fjeld in Norway; at Snarum, near Dresden; near Schmiedefeld in the Thüringerwald. Cerine occurs at Bastnäs in Sweden. Orthite occurs at Finbo and Ytterby in Sweden; also at Krageröe, etc., in Norway ; at Miask in the Ural.

In Mass., at the Bolton quarry. In Conn., at Haddam. In N. York, Moriah, Essex Co.; at Monroe, Orange Co. In N. Jersey, at Franklin. In Penn., at E. Bradford in Chester Ce.; at Easton. Amherst Co., Va. In Canada, at St. Paul's, C. W.

Muromontite and Bodenite from Marienberg, Saxony; and Michaeisonite from Brevig, are minerals related to allanite.

## ZOISITE.

Orthorhombic. $I \wedge I=116^{\circ} 40^{\prime}, O \wedge 1-\bar{\imath}=131^{\circ} 1 \frac{1^{\prime}}{} ; \dot{c}: \bar{b}: \check{a}=1 \cdot 1493$ :1.62125:1. Crystals lengthened in the direction of the vertical axis, and
vertically deeply striated or furrowed. Clearage : $i-\check{\imath}$ very perfect. Com monly in crystalline masses longitudinally furrowed. Also compact massive.
$\mathrm{H} .=6-6 \cdot 5$. G. $=3 \cdot 11-3 \cdot 38$. Lustre pearly on $i-\imath$; vitreous on surface of fracture. Color grayish-white, gray, yellowish, brown, greenish-gray, apple-green; also peach-blossom-red to rose-red. Streak uncolored. Transparent to subtranslucent. Double refraction feeble, optic-axial plane $i-\check{\imath}$; bisectrix positive, normal to $i-\bar{\imath}$; DesCl .

Var.-Lime-Zoisite. 1. Ordinary. Colors gray to white and brown. 2. Rose-red, or Thulite. G. $=3 \cdot 124$; fragile; dichroism strong, especially in the direction of the vertical axis; in this direction reddish, transversely colorless; from Norway, Piedmont. Scussurite, which forms with smaragdite the euphotide of the Alps,
 is a lime-soda zoisite.

Comp.-A lime-epidote, with little or no iron, and thus differing from epidote. Q. ratin as in epidote, $\mathrm{H}: \mathrm{Ca}=1: 4$, and $\mathrm{Ca}: \mathrm{R}: \mathrm{Si}=4: 9: 12$, whence the formula $\mathrm{H}_{2} \mathrm{Ca}_{4} \mathrm{R}_{3} \mathrm{Si}_{6} \mathrm{O}_{26}$. Analysis, Ramm., Goshen (G. $=3 \cdot 341$ ) $\mathrm{SiO}_{2} 40.06, \mathrm{HlO}_{3} 3067, \mathrm{FeO}_{3} 2 \cdot 4 \pi$, $\mathrm{CaO} 23: 91$, MgO $049, \mathrm{H}_{2} \mathrm{O} 225=9983$. The amount of iron sesquioxide varies from 0 to 6.33 p . c. ; if much more is present, amounting to a sixth atomically of the protoxide bases, the compound appears to take the monoclinic form of epidote, instead of the orthorhombic of zoisite.

Pyr., etc.-B.B. swells up and fuses at $3-3 \cdot 5$ to a white blebby mass. Not decomposed by acid; when previously ignited gelatinizes with hydrochloric acid.
Obs.-Occurs at Saualpe in Carinthia; Baireuth in the Fichtelgebirge; Sterzing, Tyrol ; Lake Geneva; Schwarzwald; Arendal, etc. In the United States, found in Vermont, at Willsboro and Montpelier. In Mass., at Goshen, Chesterfield, etc. In Penn., in Chester Co.; at Unionville, white (Unionite). In Tenn., at the Ducktown copper mines.
Jadeite is one of the kinds of pale green stones used in China for making ornaments, and passing under the general name of jade or nephrite. Mr. Pumpelly remarks that the feitsus is perhaps the most prized of all stones among the Chinese. In composition mainly a silicate of aluminum and sodium. In its high specific gravity like zoisite.

Gadolinite.-Monoclinic (DesCl.). Color greenish-black. Contains yttrium, cerium, and generally beryllium; though the last is sometimes absent, through alteration (DesCl.). Sweden; Greenland; Norway.

Mosandrite.-A silicate containing titanium, cerium, and calcium. Brevig, Norway.

## ILVAITE. Lievrite. Yenite.

Orthorhombic. $I \wedge I=112^{\circ} 3 S^{\prime}, O \wedge 1-\bar{\imath}=146^{\circ} 24^{\prime} ; c: b: \breve{a}=0 \cdot 66608$ : $1 \cdot 5004: 1$. $O \wedge 1=141^{\circ} 24^{\prime}, O \wedge 2-\check{\imath}=138^{\circ} 29^{\prime}$. Lateral faces usually striated longitudinally. Cleavage: parallel to the longer diagonal, indistinct. Also columnar or compact massive.
$\mathrm{H} .=5 \cdot 5-6$. G. $=3 \cdot 7-4 \cdot 2$. Lustre submetallic. Color iron-black, or dark grayish-black. Streak black, inclining to green or brown. Opaque. Fracture uneven. Brittle.

Comp.-Q. ratio, for $\mathrm{R}+\mathrm{R}:$ Si : $\mathrm{H}=9: 8: 1$, and for bases, including hydrogen, to silicon $5: 4$ (Städeler). Sipöcz by the analysis of entirely unaltered crystals ( $G .=4.037$ ) from Elba confirms the conclusions of Städeler in regard to the presence of chemically combined water, and adopts the same formula, viz.: $-\mathrm{H}_{2} \mathrm{Ca}_{2} \mathrm{Fe}_{4} \mathrm{FeSi}_{4} \mathrm{O}_{18}$. This requires :
 Silica $29 \cdot 34$, iron sesquioxide $19 \cdot 56$, iron protoxide $35 \cdot 21$, lime $13 \cdot 69$, water $2 \cdot 20=100$; manganese protoxide is also sometimes presentin small quantities, Ram melsberg considered the water as due to alteration.

Pyr., etc.-B.B. fuses quietly at 2.5 to a black magnetic bead. With the fluxes reacts for Iron. Some varieties give also a reaction for manganese. Gelatinizes with hydrochloric acid. Obs.-Found in Elba, and at the mine of Temperino in Tuscany. Also at Fossum and at Skeen in Norway ; in Siberia ; near Andreasberg ; near Predazzo, Tyrol; at Schneeberg; at Hebrun in Nassau; at Kangerdluarsuk in Greenland.

Reported as formerly found at Cumberland, R. I.; also at Milk Row quarry, Scmerville. Mass.

Ardennite (Dewalquite).-Near ilvaite in form. Habit prismatic; vertically striated. Composition given by the analyses, Lasaulx and Bettendorf, $\mathrm{SiO}_{2} 29.60, \mathrm{AlO}_{3} 22.50 \mathrm{MnO}$ $25 \cdot 88, \mathrm{FeO}_{3} 1 \cdot 68, \mathrm{CaO} 1 \cdot 81, \mathrm{MgO} 3.38, \mathrm{~V}_{2} \mathrm{O}_{5} 9 \cdot 20$, ign. $404=99 \cdot 09$. Color dark rosin-brown. In thin splinters transparent. Other varieties, of a bright sulphur-yellow color (but opaque and dull), contain arsenic ( $9.33 \mathrm{p} . \mathrm{c} . \mathrm{As}_{2} \mathrm{O}_{5}$ ) instead of vanadium. Between these two extremes are a series of compounds containing both arsenic and vanadium. Lasaulx regards the arsenic-ardennite as having come from the other through alteration. Locality, Ottrez in the Ardennes, Belgium. Roscoelite ( p .367 ) is another silicate containing vanadium.

## AXINITE.

Triclinic. Crystals usually broad, and acute-edged. Making $m=0$, $P=' I, u=I^{\prime}, a$ (brachyd.) : $b$ (macrod.) : $c=0 \cdot 49266: 1: 0 \cdot 45112$. Cleav age: $i-\imath(v)$ quite distinct; in other directions indistinct. Also massive, lamellar, lamellæ often curved; sometimes granular.

H. $=6.5-7 . \quad$ G. $=3 \cdot 271$, Haidinger ; a Cornish specimen. Lustre highly glassy. Color clove-brown, plum-blue, and pearl-gray; exhibits trichroism, different colors, as cinnamon-brown, violet-blue, olive-green, being seen in different directions. Streak uncolored. Transparent to subtranslucent. Fracture conchoidal. Brittle. Pyroelectric, with two axes, the analogue ( I ) and antilogue ( T ) poles being situated as indicated in f .558 (G. Rose).

[^39]phate and fluor on the platinum loop colors the flame green (boron). Not decomposed by acids, but when previously ignited. gelatinizes with hydrochloric acid.

Obs.-Axinite occurs near Bourg d'Oisans in Dauphiny ; at Santa Maria, Switzerland; at Kongsberg ; in Normark in Sweden ; in Cornwall ; in Devonshire, near Tavistock; at Phipsburg, Maine ; at Wales, Maine ; at Culd Spring, N. Y.

Danburite.*-Triclinic. $\mathrm{CaB}_{2} \mathrm{Si}_{2} \mathrm{O}_{8}=$ Silica $48 \cdot 8$, boron trioxide $28 \cdot 5$, lime $22 \cdot \%=100$. Occurs with feldsnar in imbedded masses of yellow color in dolomite, at Danbury, Ct.

## IOLITE. Cordierite. Dichroite.

Orthorhombic. In stout prisms often hexagonal. $I \wedge I=119^{\circ} 10^{\prime}$ and $60^{\circ} 50^{\prime}, O \wedge 1-\check{\imath}=150^{\circ} 49^{\prime}$. Cleavage : $i-乞$ distinct ; $i-\imath$ and $O$ indistinct. Crystals often transversely divided or foliated parallel with $O$. Twins: twinning-plane I. Also massive, compact.
H. $=7-7 \cdot 5$. G. $=2 \cdot 56-2 \cdot 67$. Lustre vitreous. Color various shades of blue, light or dark, smoky-blue ; pleochroic, being often deep blue along the vertical axis, and brownish-yellow or yellowish-gray perpendicular to it. Streak uncolored. Transparent--translucent. Frac-
 ture subconchoidal.

Comp.-Q. ratio for bases and silicon $4: 5$ or $1: 1 \frac{1}{4}$. The state of oxidation of the iron is still unascertained, and hence there is uncertainty as to the proportion between the protoxides and sesquioxides. The ratio usually deduced for $R: R: S i$ is $1: 3: 5$. The formula $R_{2} \mathrm{R}_{2} \mathrm{Si}_{5}$ $\mathbf{O}_{18}$, which corresponds to this ratio, $=$, if $\mathrm{R}=\mathrm{Mg}, \mathrm{Fe}$ and $\mathrm{Mg}: \mathrm{Fe}=2: 1$, Silica $49 \cdot 4$, qlumina $33 \cdot 9$, magnesia $8 \cdot 8$, iron protoxide $7 \cdot 9=100$.

Pyr., etc.-B.B. loses transparency and fuses at $5-5 \%$. Only partially decomposed by acids. Decomposed on fusion with alkaline carbonates.

Obs.-Iolite occurs in granite, gneiss, hornblendic, chlorite and hydro-mica sshist, and allied rocks, with quartz, orthoclase or albite, tourmaline hornblende, andalusite, and sometimes beryl. Also rarely in volcanic rocks. Occurs at Bodenmais, Bavaria; at Ujordlersoak in Greenland; at Krageröe in Norway ; Tunaberg in Sweden ; Lake Laach. At Haddam, Conn.; at Brimfield, Mass.; also at Richmond, N. H.

Alt.-The alteration of iolite takes place so readily by ordinary exposure, that the mineral is most commonly found in an altered state, or enclosed in the altered iolite. For the distinguishing characters of the different kinds of altered iolite, see Pinite, Fahlunite, etc., under Hydrous Silicates.

## Mica Group.*

The minerals of the Mica group are alike in having (1) the prismatic angle $120^{\circ}$; (2) eminently perfect basal cleavage, affording readily very thin, tongh laninæ ; (3) potash almost invariably among the protoxide bases and alumina among the sesquioxide ; (4) the crystallization approximately either hexagonal or orthorhombic, and therefore the optic axis, or optic-axial plane, at right angles (or nearly so) to the cleavage surface.

Sodium is sparingly present in some micas, and is characteristic of the hydrous species paragonite (p. 354). Lithium, rubidium, and cæsium occur in lepidolite, and lithium in some biotite. Fluorine is often present, probably replacing oxygen. Titanium is found sparingly in several kinds, and is a prominent ingredient of one species, astrophyllite. It is usually regarded as in the state of titanium dioxide replacing silica; but it is here made basic.

The species of the Mica group graduate into the hydrous micas of the Margarodite group (p. 331); and through these they also approach the foliated species of the Talc and Chlorite groups, especially the latter.

## PHLOGOPITE.*

Orthorhombic. $I \wedge I=120^{\circ}$, and habit hexagonal. Prisms usnally oblong six-sided prisms, more or less tapering, with irregrular
 sides; rarely, when small, with polished lateral planes. Cleavage basal, highly eminent. Not known in compact massive forms.
H. $=2 \cdot 5-3 . \quad$ G. $=2 \cdot 78-2.85 . \quad$ Lustre pearly, often submetallic, on cleavage surface. Color yellowish-brown to brownish-red, with often something of a copper-like reflection; also pale brownish-yellow, green, white, colorless. Transparent to translucent in thin folia. Thin laminæ tough and elastic. Optical-axial divergence $3^{\circ}-20^{\circ}$, rarely less than $5^{\circ}$.

Comp.-The bases include magnesium and little or no iron. Q. ratio $\mathrm{R}: \mathrm{Si}=1: 1$. Formula probably (Ramm.) $\mathrm{K}_{2} \mathrm{Mg}_{8} \mathrm{AlSi}_{6} \mathrm{O}_{20}=$ Silica $40 \cdot 73$, alumina $13 \cdot 93$, magnesia $32 \cdot 57$, potash $12 \cdot 77=100$.

Pyr., etc.-In the closed tube gives a little water. Some varieties give the reaction for fluorine in the open tube, while most give little or no reaction for iron with the fluxes. B. B. whitens and fuses on the thin edges. Completely decomposed by sulphuric acid, leaving the silica in thin scales.
Obs.-Phlogopite is especially characteristic of serpentine and crystalline limestone or dolomite.

Occurs in limestone in the Vosges. Includes probably the mica found in limestone at AltKemnitz, near Hirschberg ; that of Baritti, Brazil, of a golden-yellow color, having the optical angle $\tilde{5}^{\circ} 30^{\prime}$ and parallel to the shorter diagonal (Grailich); and a brown mica from limestone of Upper Hungary, affording Grailich the angle $4^{\circ}-5^{\circ}$.

Occurs in New York, at Gouverneur; at Pope's Mills, St. Lawrence Co. ; at Edwards; Warwick; Natural Bridge ; at Sterling Mine, Morris Co., N. J.; Newton, N. J.; at St. Jerome, Canada; at Burgess, Canada West.

Aspidolite (v. Kobell).-Approaches in composition a soda-phlogopite. Green. Foliated. 7.illerthal, Tyrol.

Manganophyllite.-Q. ratio for $R: R: S i=3: 1: 4$ (nearly). Foliated like the micas. Color bronze-red. Analysis, Igelström, $\mathrm{SiO}_{2} 38.50, \mathrm{HlO}_{3} 11.00, \mathrm{FeO} 3.78, \mathrm{MnO} 21 \cdot 40, \mathrm{CaO}$ $3 \cdot 20, \mathrm{MgO} 15 \cdot 01, \mathrm{~K}_{2} \mathrm{O}\left(\mathrm{Na}_{2} \mathrm{O}\right) 5 \cdot 51$, ign. $1 \cdot 60=100$. Paisberg, Sweden.

## BIOTITE.*

Hexagonal (?). $R \wedge R=62^{\circ} 57^{\prime}$ (crystals fr. Vesuvius, Hessenberg); $\dot{c}=$ 4:911126. Habit often monoclinic. Prisms commonly tabular. Cleavage : basal highly eminent. Often in disseminated

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 scales, sometimes in massive aggregations of clearable scales.
$\mathrm{H} .=2 \cdot 5-3 . \quad \mathrm{G} .=2 \cdot 7-3 \cdot 1 . \quad$ Lustre splendent, and more or less pearly on a cleavage surface, and sometimes submetallic when black; lateral surfaces vitreous when smooth and shining. Colors usually green to black, often deep black in thick crystals, and sometimes even in thin laminæ, unless the laminæ are very thin; such山in laminæ green, bluod-red; or brown br trausmitted light; rarely white.

Streak uncolored. Transparent to opaque. Optically uniaxial. Sometimes biaxial with slight axial divergence, from exceptional irregularities; but the angle not exceeding $5^{\circ}$ and seldom $1^{\circ}$.

Comp., Var.-Biotite is a magnesia-iron mica, part of the aluininum ( Al ) being replacer by iron ( Fe ), and Fe and Mg existing among the protoxide bases. Black is the prevailing color, but brown to white also occur. The results of analyses vary much, and for the rea-on already stated-the non-determination, in most cases, of the degree of oxidation of the iron; and the exact atomic ratio for the species and its limits of variatiou are therefore not precisely understoon. The Q. ratio of bee to silicon is generally $1: 1$, that is the formula in general $\mathrm{R}_{2} \mathrm{SiO}_{4}$, where $\mathrm{R}=\mathrm{K}_{2}\left(\mathrm{Na}_{2}, \mathrm{Li}_{2}\right) \mathrm{Fe}, \mathrm{Mg}(\mathrm{Ca})$, or $\mathrm{Al}, \mathrm{Fe}(3 \mathrm{R}=\mathrm{R})$.
Analyses: 1, Ballyellin; 2, Vesuvius; 3, Portland, Conn. :

|  | $\mathrm{SiO}_{2}$ | $\mathrm{H}_{1} \mathrm{O}_{3}$ | $\mathrm{FeO}_{3}$ | FeO | CaO | MgO | $\mathrm{K}_{2} \mathrm{O}$ | $\mathrm{Na}_{2} \mathrm{O}$ | $\mathrm{Li}_{2} \mathrm{O}$ | , |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| (1) | 35.55 | 17.08 | $23 \cdot 70$ | 5.50 |  | $3 \cdot 68$ | $9 \cdot 45$ | $0 \cdot 35$ |  | $4 \cdot 30=99 \cdot 61$, Haugh |
| (2) | 40.91 | 17. 79 | 3.00 | $7 \cdot 03$ | $0 \cdot 30$ | 19.04 | $9 \cdot 96$ |  |  | $=98.03$, Chodnew. |
| (3) | $\frac{2}{2} 35 \cdot 61$ | $20 \cdot 03$ | $0 \cdot 13$ | 21.85 | $1 \cdot 19 \mathrm{MnO}$ | 5:23 | $9 \cdot 69$ | 0.52 | 0.93 | $\mathrm{F} 0.76, \mathrm{TiO}_{2} 1 \cdot 46$, |

The above analyses give the ratio of unisilicates, when the water is neglected; in others the ratio of $1: 1$ is obtained only when the water is brought into account.
Pyr., etc.-Same as phlogopite, but with the fluxes it gives strong reactions for iron.
Obs.-A common constituent of many volcanic rocks. Fine specimens obtained at Vesuvius; L. Baikal; Zillerthal; Pargas; Miask; Sala. Also from Greenwood Furnace, N. Y.; Moriah, N. Y. ; Easton, Penn. ; Topsham, Me., etc.

The biotite of Vesuvius, according to the optical examination of Hintze, is monoclinis. (See also Tschermak, Min. Mitth., 1876, 187.)

## LEPIDOMELANE.

Hexagonal (?). In small six-sided tables, or an aggregate of minute scales. Cleavage: basal, eminent, as in other micas.
H. $=3$. G. $=3 \cdot 0$. Lustre adamantine, inclining to vitreous, pearly. Color black, with occasionally a leek-green reflection. Streak grayishgreen. Opaque, or translucent in very thin laminæ. Somewhat brittle, or but little elastic. Optically uniaxial ; or biaxial with a very small axial angle.

Comp.-An iron-potash mica. Q. ratio for bases and silicon $1: 1 ;$ for $R: 7$, mostly $1: 3$, but varying to 1 to more than 3 ; of doubtful limits, on account of the doubts as to the state of the iron in most of the analyses. Differs from biotite in the smaller proportion of protoxides and little Al and Mg , but appears to agree with it in optical characters.

Pyr., etc.-B.B. at a red heat becomes brown and fuses to a black magnetic globule. Easily decomposed by hydrochloric acid, depositing silica in scales. Analysis, Cooke, Rockport, Mass., $\mathrm{SiO}_{2} 39 \cdot 91, \mathrm{AlO}_{3} 16 \cdot 73, \mathrm{FeO}_{3} 12 \cdot 07$, $\mathrm{FeO} 17 \cdot 48$, Mn() $0 \cdot 504$, $\mathrm{MgO} 0 \cdot 62, \mathrm{~K}_{2} \mathrm{O} 10 \cdot 66$, $\mathrm{Na}_{2} \mathrm{O}\left(\mathrm{Li}_{2} \mathrm{O}\right) 0.59, \mathrm{H}_{2} \mathrm{O} 1 \cdot 50, \mathrm{~F} 0.45=100$.

Obs.-Occurs at Persberg in Wermland, Sweden; at Abborforss in Finland; in Ireland, in Donegal and Leinster Cos.; at Ballyellin, etc. From Cape Ann, Mass. (Annite).

Astropirllite.-Usually in tabular prisms. Color bronze-yellow. Analysis, Pisani, SiO: $32 \cdot 22, \mathrm{TiO}_{2} 7 \cdot 66, \mathrm{AlO}_{3} 4 \cdot 32, \mathrm{FeO}_{3} 4 \cdot 05, \mathrm{FeO} 25 \cdot 48, \mathrm{MnO} 10 \cdot 70, \mathrm{MgO} 1 \cdot 37, \mathrm{CaO} 1 \cdot 2 \cdot, \mathrm{Na}_{2} \mathrm{O}$ $2 \cdot 71, \mathrm{~K}_{2} \mathrm{O}$ f.29, $\mathrm{H}_{2} \mathrm{O} 2 \cdot 01=99 \cdot 03$. Brevig, Norway; El Paso County, Colorado.

MUSCOVITE. Kaliglimmer, Germ.*
Moroclinic (Tschermak). $I \wedge I=120^{\circ}$. Cleavage: basal eminent, occasionally also separating in fibres parallel to a diagonal. Twins: often observable by internal markings, or by polarized light ; composition parallel
to 1 consisting of six individuals thus united; sometimes a union of $I$ ic i-v. Folia often aggregated in stellate, plumose, or globular forms; cr ir scales, and scaly massive.

H. $=2-2 \cdot 5$. G. $=2 \cdot 75-3 \cdot 1$. Lustre more or less pearly. Color white, gray, brewn, hair-brown, pale green, and violet, yellow, dark olive-green, rarely rose-red ; often different for transmitted and reflected light, and different also in vertical and transverse directions. Streak uncolored. Transparent to translucent. Thin laminæ flexible and elastic, very tough. Double refraction strong; optic-axial angle $44^{\circ}-78^{\circ}$; the axial plane makes an angle of $88^{\circ} 20^{\prime}$ (Tschermak) with the base.

Comp.-The quantivalent ratio for bases and silicon is generally $4: 5$ (1. 11 $)$, rarely 3. 4, etc. Water is generally present, sometimes as much as $5 \mathrm{p} . \mathrm{c}$; ; and the kinds containing from 3 to 5 p. c. water have been referred to the species margarodite ( p .353 ). If the water is regarded as chemically combined, that $i s$, as basic, the $Q$. ratio for $R: \not \subset: S i$ is then $=1: 3: 4(\mathrm{R}: \mathrm{Si}=1: 1)$, also $1: 6: 8,1: 2: 4,1: 3: 5$, etc. $\frac{1}{R}$ here is potassium (K) mostly, but also hydrogen (H). $\quad \mathrm{R}=$ aluminum mostly, also iron. Fluorine is often present, but at most not more than about 1 p . c. Analysis, Smith aud Brush, Monroe, Ct., $\mathrm{SiO}_{2} 46^{\circ} 50$, $\mathrm{AlO}_{3} 33 \cdot 91$. $\mathrm{FeO}_{3} 2 \cdot 60, \mathrm{MgO} 0 \cdot 90 \quad \mathrm{Na}_{2} \mathrm{O} 2 \cdot 70, \mathrm{~K}_{2} \mathrm{O}^{\prime} \cdot 32, \mathrm{H}_{2} \mathrm{O} 4 \cdot 63, \mathrm{~F} 0 \cdot 82, \mathrm{Cl} 0 \cdot 31=99 \cdot 78$.

Pyr., etc.-In the closed tube gives water, which with brazil-wood often reacts for fluorine. B.B. whitens and fuses on the thin edges ( $\mathrm{F} .=5 \cdot 7$, v. Kobell) to a gray or yellow glass. With fluxes gives reactions for iron and sometimes manganese, rarely chromium. Not decomposed by acids. Decomposed on fusion with alkaline carbonates.

Obs.-Muscovite is the most common of the micas. It is one of the constituents of granite, gneiss, mica schist, and other related rocks, and is occasionally met with in granular limestone, trachyte, basalt, iava; and occurs also disseminated sparingly in many fragmental rocks. Coarse lamellar aggregations often form the matrix of topaz, tourmaline, and other mineral species in granitic veins.

Siberia affords laminæ of mica sometimes exceeding a yard in diameter; and other remarkable foreign localities are Finbo in Sweden, and Skutterud in Norway. Fuchsite or chromium mica occurs at Greiner in the Zillerthal, at Passeyr in the Tyrol, and on the Dorfner Alp, as well as at Schwarzenstein.

In $N$. Hamp., at Acworth, Graftnn, etc., in granite, the plates at times a yard across and perfectly transparent. In Maine, at Paris; at Buckfield. In Mass., at Chesterfield ; at Goshen. In Conn.. in Portland; near Middletown. In N. York, near Warwick; Edenville; in the town of Edwards. In Penn., at Pennsbury; at Unionville; Delaware Co., at Middletown. Ln Maryland, at Jones's Falls. In western North Carolina, where it is mined.

LEPIDOLITE.* Lithia Mica. Lithionglimmer, Germ.
Orthorhombic. $I \wedge I=120^{\circ}$. Forms like those of muscovite. Cleav. age: basal, highly eminent. Also massive scaly-granular, coarse or fine.
H. $=2 \cdot 5-4$. G. $=2 \cdot 84-3$. Lustre pearly. Color rose-red, violet-gray, or
lilac, yellowish, grayish-white, white. Translucent. Optic-axial angle $70^{\circ}-78^{\circ}$; sometimes $45^{\circ}-60^{\circ}$.

Comp.-Q. ratio for bases and silicon mostly $1: 1 \frac{1}{2}$; and for $\frac{1}{R}: \mathrm{R}: \operatorname{Si}=1: 3: 6$, or $1: 4$ : 8; the formula in the iatter case is $\mathrm{R}_{6} \mathrm{Hl}_{4} \mathrm{Si}_{1!} \mathrm{O}_{39} . \frac{\mathrm{R}}{\mathrm{R}}$ includes potassium, also lithium, rubidium, and cesium; and, in the Zinnwald mica, thallium has been detected. Fluorine is present, and the ratio to oxygen mostly $1: 12$. Analysis, Reuter, from Rozena, $\mathrm{SiO}_{2} 50 \cdot 43$,

Pyr., etc.-In the closed tube gives water and reaction for fluorine. B.B. fuses with intumescence at $2-2 \cdot 5$ to a white or grayish glass, sometimes magnetic, coloring the flame purplish-red at the moment of fusion (lithia). With the fluxes some varieties give reactions for iron and manganese. Attacked but not completely decomposed by acids. After fusion, gelatinizes with hydrochloric acid.
Obs.-Occurs in granite and gneiss, especially in granitic veins, and is associated sometimes with cassiterite, red, green, or black tourmaline, amblygonite, etc. Found near Utö in Sweden ; at Zinnwald in Bohemia; Penig, etc. in Saxony ; in the Ural; at Rozena in Moravia ; on Eiba; at St. Michael's Mount in Cornwall. In the United states, at Paris and Hebron, Me. ; near Middletown, Conn.

Named lepidolite from ismis, scale, after the earlier German name Schuppenstein, alluding to the scaly structure of the massive variety of Rozena.

Chyopiyllite (Cooke).-Q. ratio $\mathrm{R}: \not \mathrm{R}: \mathrm{Si}=3: 4: 14$, with $\mathrm{R}=\mathrm{Fe}_{2}, \mathrm{~K}_{2}, \mathrm{Li}_{2}(\mathrm{Na}, \mathrm{Rb}, \mathrm{Cs},)_{2}$ and $\mathrm{R}=\mathrm{Al}$. Orthorhombic. In scales like the micas. Color by transmitted light emerald green. Cape Ann, Mass.

## Scapolite Group.

In the species of the Scapolite group, the quantivalent ratio varies from $1: 1: 2,1: 2: 3,1: 3: 4$, to $1: 2: 4$ and $1: 2: 6 \frac{1}{2}$, but the species are closely alike in the square-prismatic forms of their crystals, in the small number and the kinds of occurring planes, and in their angles. The species are white, or grayish-white, in color, except when impure, and then rarely of dark color ; the hardness $5-6 \cdot 5$. G. $=2 \cdot 5-2 \cdot 8$. The alkali-metal present, when any, is sodium, with only traces of potassium. An increase in the amount of alkali is accompanied by an increase in the silica.

## MEIONITE.*

'Tetragonal: $0 \wedge 1-i=156^{\circ} 18^{\prime} ; \dot{c}=0 \cdot 439$. Sometimes hemihedral in the planes $3-3$, the alternate being wanting. Cleavage: $i-i$ and $I$ rather perfect, but often interrupted.
$H .=5 \cdot \check{\circ}-6 . \quad$ G. $=2 \cdot 6-2 \cdot 74$. Lustre vitreous. Colorless to white. Transparent to translucent; ; often much cracked within.

Comp.-Q. ratio for $\mathrm{R}: \mathrm{R}: \mathrm{Si}=1: 2: 3$; formula $\mathrm{R}_{6} \mathrm{R}_{4} \mathrm{Si}_{9} \mathrm{O}_{36}$. If $\mathrm{R}=$ $\mathrm{Ca}: \mathrm{Na}_{2}=10: 1$, and $\mathrm{R}=\mathrm{tl}$; this is equivalent to Silica $41 \cdot 6$, alumina $31 \cdot \%$, lime $24 \cdot 1$, soda $2 \cdot 6=100$. Neminar has found that meionite loses 1 p . c. water at a very high temperature, so that R must be also replaced by $\mathrm{H}_{2}$; his analysis gives approximately the ratio $1: 2: 3$.
Pyr., etc.-B.B. fuses with intumescence at 3 to $a$ white blebby glass. Decomposed by acid withou gelatinizing (v. Rath).

Obs.-Occurs in small crystals in geodes, usually in limestone blocks, on Monte Somua, near Naples.

## WERNERITE.* Scapolite.

Tetragonal: $O \wedge 1-i=156^{\circ} 14 \frac{1}{2}^{\prime} ; \quad \dot{c}=0.4398$. Often hemihedrai in
 planes $3-3$ and $i-2$ (p. 30). Clearage: $i-i$ and $I$ rather distinct, but interrupted. Also massive, granular, or with a faint fibrous appearance; sometimes colmenar, $\mathrm{H} .=5-6 . \quad \mathrm{G} .=2 \cdot 63-2 \cdot 8$. Lustre vitreous to pearly externally, inclining to resinous; cleavage and crossfracture surface vitreous. Color white, gray, bluish, greenish, and reddish, usually light. Streak uncolored. Transparent-faintly subtranslucent. Fracture subconchoidal. Brittle.

Comp.-Q. ratio for $\mathrm{R}: \mathrm{R}: \mathrm{Si}=1: 3: 4(\mathrm{R}+\mathrm{R}: \mathrm{Si}=1: 1)$; formula $\mathrm{RRSi}_{2} \mathrm{O}_{8}=\mathrm{Ca}\left(\mathrm{Na}_{2}\right) \mathrm{AlSi}_{2} \mathrm{O}_{8}$. Analysis, v. Rath, Pargas, $\mathrm{SiO}_{2} 45 \cdot 46, \mathrm{AlO}_{3} 30 \cdot 96, \mathrm{CaO}$ $17 \cdot 22, \mathrm{Na}_{2} \mathrm{O} 2 \cdot 29, \mathrm{~K}_{2} \mathrm{O} 1 \cdot 31, \mathrm{H}_{2} \mathrm{O} 1 \cdot 29=98 \cdot 53$. Some varieties vary widely from the above ratio.

Pyr., etc.-B.B. fuses easily with intumescence to a white blebby glass. Imperfectly de composed by hydrochloric acid.

Diff.-Recognized by its square form ; resembles feldspar when massive, but has a characteristic fibrcus appearance on the cleavage surface ; it is also more fusible, and has a higher specific gravity.

Obs.-Occurs in metamorphic rocks; sometimes in beds of magnetite accompanying limestone. Some localities are: Arendal, Norway; Wermland; Pargas, Finland; L. Baikal, etc. In the following those of the wernerite and ekebergite are not yet distinguished. In Mass., at Bolton; Westfield. In Conn., at Monroe. In N. York, in Warwick; in Orange and Essex Co., etc. In N. Jersey, at Franklin and Newton. In Canadu, at G. Calumet Id.; at Hunterstown; Grenville.

The following are other members of the scap slite group :
Sarcolite.-Q. ratio for $R: \mathrm{R}: \mathrm{Si}=1: 1: 2$. In minute flesh-red crystals at Mt Somma.

Paranthite.-Q. ratio=1:3:4. Ekebergite. Q. ratio=1:2:4 $\frac{1}{2}$, containing 6-8 p. o. soda. Mrzzonite. Q. ratio $=1: 2: 5 \frac{1}{4}$, containing 10 p. c. soda. In crystals at Mt. Somma, Dipyre. Q. ratio=1:2:6, and for $\mathrm{Ca}: \mathrm{Na}_{2}=1: 1$. Marialite. Q. ratio=1:2:6, and for $\mathrm{Ca}: \mathrm{Na}_{2}=1: 2$.

## Nephelite Group.

NEPHELITE. Nepheline.
Hexagonal. $O \wedge 1=135^{\circ} 55^{\prime} ; \dot{c}=0.839$. Usual forms six-sided and

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Vesuvius. twelve-sided prisms with plane or modified summits. Fig. 569, summit planes of a crystal. Cleayage: $I$ distinct, $O$ imperfect. Also massive, compact; also thin columnar.
II. $=55-6 . \quad$ G. $=2.5-2 \cdot 65$. Lustre vitrenusgreasy; a little opalescent in some varicties. Colorless, white, or yellowish; also when massive, darkgreen, greenish or bluish-gray, brownish and brickred. Transparent-opaque. Fracture subconchoidal. Donble refraction feeble; axis negative.

Var.-1. Glassy, or Sommite. Usually in small crystals os grains, with vitreous lustre, first found on Mt. Somma, in the region of Vesuvius. Davyne and cavolinite belong here.
8. Elceolite. In large coarse crystals, or massive, with a greasy lustre.

Comp.-Somewhat uncertain, as all analyses give a little excess of silica beyond what is required for a unisilicate. Assuming that nephelite is a true unisilicate, the Q. ratio for ${ }^{\mathrm{I}}$ $\mathrm{R}: \mathrm{R}: \mathrm{Si}=1: 3: 4$, and the formula is ( $\mathrm{Na}, \mathrm{K})_{2} \mathrm{AlSi}_{2} \mathrm{O}_{8}$ (Ramm.) ; some of the $\mathrm{Na}_{2}$ being replaced by Ca . Analysis, Scheerer, Vesuvius, $\mathrm{SiO}_{2} 44 \cdot 03, \mathrm{AlO}_{3} 33 \cdot 28, \mathrm{FeO}_{3}\left(\mathrm{HfnO}_{3}\right) 0.65$, CaO $1 \cdot 7 \%$. $\mathrm{Na}_{2} \mathrm{O} 15 \cdot 44, \mathrm{~K}_{2} \mathrm{O} 4.94, \mathrm{H}_{2} \mathrm{O} 0 \cdot 21=100 \cdot 32$. The variety Elcoolite has the same composition.

Pyr., etc.-B.B. fuses quietly at 3.5 to a colorless glass. Gelatinizes with acids.
Diff.-Distinguished by its gelatinizing with acids from scapolite and feldspar, as also from apatite, from which it differs too in its greater hardness. Massive varieties have a characteristic greasy lustre.

Obs.-Nephelite occurs both in ancient and modern volcánic rocks, and also metamorphic rocks allied to granite and gneiss, the former mostly in glassy crystals or grains (sommite), the latter massive or in stout crystals (elceolite). Nephelite occurs in crystals in the older lavas of Somma; at Capo di Bove, near Rome; in doleryte of Katzenbuckel, near Heidelberg, etc. Elæolite is found in Norway ; in the Ilmen Mts. ; Urads; at Litchfield, Me. $;$ in the Ozark Mts., Arkansas.

Named nepheline by Haüy (1801), from veфe入h, a cloud, in allusion to its becoming cloudy when immersed in strong acid; elcoolite (by Klaproth), from $\dot{\varepsilon} \lambda a \iota o v$, oil, in allusion to its greasy lustre.

Gieseckite is shown by Blum to be a pseudomorph after this species (see p. 330).
Cancrinite.*-Hexagonal, and in six- and twelve-sided prisms, sometimes with basal edges replaced; also thin columnar and massive. H.=5-6. G. $=2 \cdot 42-2 \cdot 5$. Color white, gray. yellow, green, blue, reddish; streak uncolored. Lustre subvitreous, or a little pearly or greasy. Transparent to translucent.

Comp.-Same as for nophelite, with some $\mathrm{RCO}_{3}$ and water. Analysis, Whitney, Litchfield, Me ., $\mathrm{SiO}_{2} 37.42, \mathrm{AlO}_{3} 27.70, \mathrm{CaO} 3.91, \mathrm{Na}_{2} \mathrm{O} 20.98, \mathrm{~K}_{2} \mathrm{O} 0.67, \mathrm{CO}_{2} 5.95 . \mathrm{H}_{2} \mathrm{O} 2.82, \mathrm{FeO}_{3}$ $\left(\mathrm{H}_{\mathrm{HnO}}^{3}\right.$ ) $0 \cdot 86=100 \cdot 31$.

PYR., ETC.-In the closed tube gives water. B.B. loses color, and fuses (F.=2) with intumescence to a white blebby glass, the very easy fusibility distinguishing it readily from nephelite. Effervesces with hydrochloric acid, and forms a jelly on heating, but not before.

Obs.-Found at Miask in the Urals; at Barkevig, Norway; at Ditro in Transylvania (ditroyte) ; at Litchfield, Me.

## SODALITE.

Isometric. In dodecahedrons. Cleavage: dodecahedral, more or less distinct. Twins: see f. 272, p. 93. Also massive.
$\mathrm{H} .=5 \cdot 5-6 . \quad \mathrm{G} .=2 \cdot 136-2 \cdot 401$. Lustre vitreous, sometimes inclining to greasy. Color gray, greenish, yellowish, white ; sometimes blue, lavenderblue, light red. Subtransparent-translucent. Streak uncolored. Fracture conchoidal-meven.

Comp. $-3 \mathrm{Na}_{2} \mathrm{AlSi}_{2} \mathrm{O}_{8}+2 \mathrm{NaCl}=$ Silica $37 \cdot 1$, alumina $31 \cdot 71$, soda $25 \cdot 55$, chlorine $7 \cdot 31=101 \cdot 65$. flome varieties contain considerably less chlorine.
Pyr., etc.-In the closed tube the blue varieties become white and opaque. B.B. frises with intumescence, at $3 \cdot 5-4$, to a colorless glass. Decomposed by hydrochloric acid, with separation of gelatinous silica.
Obs.-Occurs in mica slate, granite, syenite, trap, basalt, and volcanic rocks, and is often associated with nephelite (or elæolite) and eudialyte. Found in West Greenland; on Monte Somma; in Sicily; at Miask, in the Ural ; near Brevig, Norway. A blue variety occura at Litchfield, Me., and at Salem, Mass.
Micnosommite.-Occurs in very minute hexagonal crystals in masses of leucitio lava ejected from Mt. Somma. Composition : a unisilicate of potassium, calcium, and aluminum, with small quantities of sodium chloride and calcium sulphate.

## HAÜYNITE.

Isometric. In dodecahedrons, octahedrons, etc. Cleavage : dudecaliedral distinct. Commonly in rounded grains often looking like crystals with a fused surface.
H. $=5 \cdot 5-6$. G. $=2 \cdot 4-2 \cdot 5$. Lustre vitreons, to somewhat greasy. Colos bright blue, sky-blue, greenish-blue; asparagus-green. Streak slightly bluish to colorless. Subtransparent to translucent. Fracture flat conchoidal to meven.

Comp. $-2 \mathrm{Na}_{2}(\mathrm{Ca})+1 \mathrm{Si}_{2} \mathrm{O}_{8}+\mathrm{CaSO}_{4}$; if in the silicate $\mathrm{Na}_{2}$ is replaced by Ca , the atomic ratio here being $5: 1$, this gives Silica $34 \cdot 13$, alumina $29 \cdot 18$, lime $10 \cdot 62$, soda $14 \cdot 69$, sulphur trioxide $11 \cdot 38,=100$. A little potassium is also often present.
Pyr., etc.-In the c'osed tabe retains its color. B.B. in the forceps fuses at 4.5 to a white glass. Fused with soda on charcoal affords a sulphide, which blackens silver. Decomposed by hydrochloric acid with separation of gelatinous silica.

Obs.-Occurs in the Vesuvian lavas, on Somma; in the lavas of the Campagna, Rome; in basalt at Niedermendig and Mayen, L. Laach, etc.

Nosite (Nosean). - A soda-haïynite; $2 \mathrm{Na}_{2} \mathrm{AlSi}_{2} \mathrm{O}_{8}+\mathrm{Na}_{2} \mathrm{SO}_{4}$, with also a little calcium. Isometric; often graiular massive. Common as a microscopic ingredient of most phonolytes. Lake Laach, etc.
Lapis-LaZULI (Lasurstein, Germ.).-Not a homogeneous mineral according to Fischer and Vogelsang. The latter calls it "a mixture of granular calcite, ekebergite, and an isometrio, ultramarine mineral, generally blue or violet." Much used as an ornamental stone.

## LEUCITE.*

Tetragonal, according to v. Rath. $\dot{c}=0.52637$. Usual form as in f. 570, closely resembling a trapezohedron. Twins:
 twinning-plane $2-i$; crystals often very complex, consisting of twinned lamellæ, as indicated by the striations on the planes. Often disseminated in grains; rarely massive granular.
$\mathrm{H} .=5 \cdot 5-6$. G. $=2 \cdot 44-2 \cdot 56$. Lustre vitreous. Coinr white, asl-gray or smoke-gray. Streak mucolored. Translucent-opaque. Fracture conchoidal. Brittle. Optically uniaxial; double refraction weak, negative (from Aquacetusa), positive (from Frascati).

Comp.-Formula $\mathrm{K}_{2} \mathrm{AlSi}_{4} \mathrm{O}_{12}=$ Silica 55.0 , alumina 23.5 , potash $215=100$. Q. ratio for $\mathrm{K}: \mathrm{Al}: \mathrm{Si}=1: 3: 8$, for bases to silicon $1: 2$.

Pyr., etc.-B.B. infusible; with cobalt solution gives a blue cclor (alumina). Decomposed by hydrochloric acid without gelatinization.

Diff.-Distinguished from analcite by its infusibility and greater hardness.
Obs.-Leucite is confined to volcanic rocks, and is common in those of certain parts of Eurnpe; also found in those of the western United States. At Vesuvius and some other parts of Italy it is tl ickly disseminated through the lava in grains. It is a constituent in the nephelin-doleryte of Merches in the Vogelsberg; abundant in trachyte between Lake Laach and Andernach, on the Rhine.

The question as to whether the crystals of leucite belong to the isometric or the tetragonal asstem has excited much discussion. Hirschwald (Tsch. Min Mitth., 1875, 227) shows that While implanted crystals are sometimes distinctly tetragonal, others, especially those which are imbedded, are as clearly isometric, while between the two there exist many transition cases. He claims that the mineral is in fact isometric, but having a polysymmetric development, there existing a wide variajon from the isometric type. The question cannot be con widered as entirely decided.

## Feldspar Group.*

The feldspars are characterized by specific gravity below $2 \cdot 8$; lharducss 6 to 7 , fusibility 3 to 5 ; oblique or clinohedral crystallization ; prismatic angle near $120^{\circ}$; two easy cleavages, one basal, the other brachydiagonal, inclined together either $90^{\circ}$, or very near $90^{\circ}$; cleavage a prominent feature of many massive kinds, and distinct in the grains of granular varieties, giving them angular forms; close isomorphism, and a general resemblance in the systems of occurring crystalline forms; transition from graunar varieties to compact, hornstone-like kinds, called felsites, which sometimes occur as rocks; often opalescent, or having a play of colors as seen in a direction a little oblique to $i-i$; often aventurine, from the dissemination of microscopic crrstals of foreign substances parallel for the most part to the planes $O$ and $I$.

The bases in the protoxide state are calcium, sodinm, potassium, and in one species barium; the sesquioxide base is only aluminum; the quantivalent ratio of $R: Z$ is constant, $1: 3$; while that of the silicon and bases varies from $1: 1$ to $3: 1$, the amount of silicon increasing with the increase of the alkali metals, and becoming greatest when alkalies are the only protoxides.

The included species are as follows:

| Anorthite | Lime feldspar | Crystallization. Triclinic | Approx. Q. ratio R, $\mathbb{R}$ $1: 3: 4$ |
| :---: | :---: | :---: | :---: |
| Labradorite | Lime-soda feldspar | " | 1:3:6 |
| Hyalopilane | Baryta-potash feldspar | Monoclinic | 1:3:8 |
| Andesite | Soda-lime feldspar | Triclinic | 1:3:8 |
| Oligoclase | " " ، | " | 1:3:9 |
| Albite | Soda feldspar | 6 | 1:3:12 |
| Orthoclase | Potash feldspar | Monoclinic | 1:3:12 |

To the above list should be added, according to DesCloizeaux, the triclinic, potash feldspar, microcline, which has the composition of orthoclase.

The above ratios are only approximate, for the analyses show a wide variation in the amount of silicon, and an exactly proportionate variation in the amount of alkali; the two elements vary in most cases, as has been long recognized, according to a simple law. There seems hence to be a gradual transition between the successive species ; but this is due, in part, to mixtures produced by contemporaneous crystallization (compare perthite, p 326 , and the description of microcline, p. 326).

The unisilicate ratio of 1:1 for bases and silicon is found in anorthite only, as shown above. With Ca alone, as in this species, the $\mathbf{Q}$. ratio for Al and Si is $3: 4$; with $\mathrm{Na}_{2}$ alone, $3: 12$; and for kinds containing combinations of the two, exact combinations of these ratios, $m \mathrm{Na}_{2}$ : $n \mathrm{Ca}$, giving the ratio $3: \frac{4 m+12 n}{m+n}$.

An explanation of the above fact, and of the variation in ratio shown by analyses, was offered by Ifunt, and has since heen developed by Tschermak. The existence of two distinct triclinio feldspars is assumed: anorthite $\mathrm{Ca}+1 \mathrm{Si}_{2} \mathrm{O}_{8}^{\prime}$, and albite $\mathrm{Na}_{2} \mathrm{AlSi}_{6} \mathrm{O}_{10}$, and the other species (sometimes embraced under the general term Plagioclase) are regarded as due to isomorphous mixtures of these two members i. different proportions. They have th $n$ n the general formula $\left\{\begin{array}{l}m\left(\mathrm{Ca}_{2}+1 \mathrm{Si}_{2} \mathrm{O}_{8}\right) \\ n\left(\mathrm{Na}_{2} \mathrm{HlSi}_{6} \mathrm{O}_{16}\right)\end{array}\right.$. For labraãc:ite the ratio of $m: n$ is mostly $3: 2$, also $3: 1$, etc.; for andesite the ratio of $m: n$ varies about $1: 2$, and for oligoclase the ratio of $m: n$ is $3: 10$, also $1: 3$, etc. In accordance with the above formula, if $\mathrm{Ca}: \mathrm{Na}=\mathbf{6}: 1$, ther $\mathrm{Al}: \mathrm{Si}=$ $1: 2 \cdot 308$; for $\mathrm{Ca}: \mathrm{Na}=3: 1, \mathrm{Al}: \mathrm{Si}=1: 1 \cdot 257$; for $\mathrm{Ca}: \mathrm{Na}=1: 1$, $\mathrm{Al}: \mathrm{Si}=1: 3 \cdot 33$; foz $\mathrm{Ca}: \mathrm{Na}=1: 3, \mathrm{Al}: \mathrm{Si}=1: 4 \cdot 4$; for $\mathrm{Ca}: \mathrm{Na}=\mathrm{i}: 6, \mathrm{Al}: \mathrm{Si}=1: 5$.

This method of viewing the feldspar species has the advantage of explaining the wide variation in their composition, and is generally accepted among Germav mineralogists. DesCloizeaux regards his observations upon the optical characters of the feldspars (see p. 298) a showing that they are in fact distinct speries, and not indeterminate isomorphous mixtures.

Optical propertics of the triclinic feldspars. -The following table contains the mure import. ant optical properties of the feldspar species as determined by DesCloizeaux (C. R., Feb. 8, 1875, and April 17, 1876). Bx=Bisectrix.

| cute bisec | Anorthite. always - | Labradorite. always + | Oligoclase. generally sometimes + | Albite. always + | Microchine. always - |
| :---: | :---: | :---: | :---: | :---: | :---: |
| Angle made by the +Bx . with a normal to $i-\imath$ ( $g$ ) | the Bx. has no simple | $30^{\circ} 40^{\prime}$ | $18^{\circ} 10^{\prime}$ | $15^{\circ}$ | $15^{\circ} 26^{\prime}$ |
| Same, with normal to $O(p) . . . . . . . . . . .$. | relation to the planes | 56 | $68^{\circ}$ | $78^{\circ} 35^{\prime}$ |  |
| Angle made by the line in which the plane of the optic-axes cuts $i-\check{c}$, with edge $i-\check{\imath} / O\left(g^{\prime} / p\right)$ | observed on the crystals. | $27^{\circ}$ | Line parallel to the edge $O \mid i-\check{-}$. | $20^{\circ}$ |  |
| Same, with edge $i$ ( $g^{\prime} m$ ) $\qquad$ |  | $37^{\circ} 25^{\prime}-36^{\prime} 25^{\prime}$ |  | $96^{\circ} 28^{\prime}$ (front) |  |
| Ordinary dispersion. | $v(-\mathrm{Bx}$. | $>v(+\mathrm{Bx}$. $)$ | $\rho<v(+B x$. | $\rho<r\left(+B x_{0}\right)$ |  |
| Parallel or perpendicular to plane of polarization. | Inclined. | Crossed; also slight inclined. | Crossed; also slight in clined. | Inclined: probably also slight horizontal. | $\begin{gathered} \text { Horizontal } \\ (- \text { Bx. also } \\ \text { inclined } \\ (+ \text { Bx. }) \end{gathered}$ |
| Optic-axial angle (in air)for red rays.......- for blue rays..... | $\begin{aligned} & 84^{\circ} 58^{\prime} \\ & 85^{\circ} 59^{\prime} \end{aligned}$ | $88^{\circ} 15^{\prime}$ <br> $87^{\circ} 48^{\prime}$ | ( ${ }^{89^{\circ}} 3{ }^{\prime} 5^{\prime}$ | $80^{\circ} 39^{\prime}$ $81^{\circ} 59^{\prime}$ | $87^{\circ} 54^{\prime}$ |
|  |  | (Labrador) | (Sunstone, Tvedestrand) | (Roc tourné) | Amazonst'ne, Mursinsk. |

The axial divergence is quite constant for albite, labradorite, and anorthite, but varies for oligoclase even in different sections taken from the same specimen. Andesine ( $q$ - v.) is regarded by DesCloizeaux as an altered oligoclase.

DesCloizeaux gives the following method of distinguishing between the feldspars by optical means: It is necessary to obtain a transparent plate parallel to the easiest cleavage ( $O$ ). Such sections obtained from crystals or lamellar masses of albite, oligoclase, labradorite, and the majority of those of microcline, show hemitropic bands, more or less close together, arranged along the plane parallel to the second cleavage ( $i-\stackrel{\imath}{\text { r }}$; ; for orthoclase and microline in simple crystals, two sections placed in opposite positions serve to produce the same effect. These sections are thus brought between the crossed Nicols of a polarization-microscope.
(1) For orthoclase the maximum extinction takes place when the two sections are parallel to their plane of contact; the edge $0 / i-\breve{\imath}$ being in the plane of polarization of the microscope.
(2) For microcline, the whole structure consists of a multitude of very fine parallel bands; the section may show microcline alone, either hemitropic or not hemitropic, or microcline and orthoclase ; the extinction can take place at $30^{\circ} 54^{\prime}$ between the adjoining bands of the same plate of the macle (microcline alone), at $30^{\circ} 54^{\prime}$ between the two plates of the macle (microcline in bands), or at $15^{\circ} 27^{\prime}$ between the adjoining bands (microcline and orthoclase). In the last case the whole of two lamellæ of the macle show at the same time an extinction oblique to the plane of composition, belouging to the microcline, and one parallel to this plane for the orthoclase.
(3) For albite, the extinction between two bands takes place at an angle of $6^{\circ} 32^{\prime}$.
(4) For oligoclase, the extinction is simultaneous in the two bands, and when the plane of composition coincides with the plane of polarization of the polariscope, it shows that the structure is homogeneous.
(5) For labradorite, the extinction takes place at $10^{\circ} 24^{\prime}$ between the alternatc lines of the hemitropic lamellæ.

It follows from this that a plane normal to the plane of the axes cuts the base along a line making with the edge $0 / i-\imath$ the following angles:
$0^{\circ}$ in orthoclase,
$15^{\circ} 27^{\prime}$ in microcline,
$3^{\bullet} 16^{\prime}$ in albite,
$5^{\circ} 12^{\prime}$ in labradorite.

[^40]Diff.—The feldspars arre distinguished from other species by the characters already stated. prominent among which are : cleavage in two directions, nearly or quite at right angles tc each other ; also hardness, etc.

The triclinic feldspars can in most cases be distinguished from orthoclase by the fine striation due to repeated twinning. This striation can often be seen by the unaided eye upon the cleavage face ( $O$ ). And its existence can always be surely tested by the examination of a thin snotion in polarized light, the alternate bands of color showing the same fact.

The separation of the different triclinic species can be surely made by complete analysis only, or at least by the determination of the amount of alkali present. The degree of fusibility, the color of the flame, and the effect produced by digestion in acids, are often important aids. In the hands of a skilled observer the optical examination may give decisive results.

ANORTHITE. Indianite.
Triclinic. $\quad \dot{c}: \bar{b}: \breve{a}=0.86663: 1.5754 S: 1 . \quad I \wedge l^{\prime}=120^{\circ} 31^{\prime}, O \wedge i-\check{\circ}$, (over $2-\breve{-}$ ) $=94^{\circ} 10^{\prime}, O \wedge I^{\prime}=114^{\circ} 6 \frac{1}{2}^{\prime}, O \wedge I=110^{\circ}$ $40^{\prime}, O \wedge 2-\overline{1}=98^{\circ} 46^{\prime} ; a=93^{\circ} 13 \frac{1^{\prime}}{}{ }^{\prime}, \beta=115^{\circ} .55 \frac{1_{2}^{\prime}}{}$, $\gamma=91^{\circ} 11 \frac{1^{\prime}}{}$ Clearage: $O, i-\check{\iota}$ perfect, the latter least so. Twins similar to those of albite. Also massive. Structure granular, or coarse lamellar.
$\mathrm{H}=6-7 . \quad \mathrm{G} .=2 \cdot 66-2 \cdot 78$. Lustre of cleavage planes inclining to pearly; of other faces vitreous. Color white, grayish, reddish. Streak uncolored. Transparent - translucent. Fracture conchoidal. Brittle.


Var.-Anorthite was described from the glassy crystals of Somma. Indianite is a white, grayish, or reddish granular anorthite from India, first described in 1802 by Count Bournon.

Comp.-Q. ratio for $\mathrm{R}: \mathrm{Al}: \mathrm{Si}=1: 3: 4$. Formula $\mathrm{CaAlSi}_{2} \mathrm{O}_{8}=$ Silica $43 \cdot 1$, alumina $36 \cdot 8$, lime $20^{\circ} 1=100$. The alkalies are sometimes present in very small amounts.

Pyr., etc.-B.B. fuses at 5 to a colorless glass. Decomposed by hydrochloric acid, with separation of gelatinous silica.

Obs.-Occurs in some granites; occasionally in connection with gabbro and serpentine rocks; in some cases along with corundum ; in many volcanic rocks. Found in the old lavas in the ravines of Monte Somma; Pesmeda-Alp, Tyrol ; in the Faroe islands; in Iceland; near Bogoslovsk in the Ural, etc.

Bytownite has been shown by Zirkel to be a mixture. Bytown, Canada.

## LABRADORITE.

Triclinic. $I \wedge I=121^{\circ} 37^{\prime}, O \wedge i-\imath ้=93^{\circ} 20^{\prime}, O \wedge I=110^{\circ} 50^{\prime}, O \wedge I^{\prime}$ $=113^{\circ} 34^{\prime}$; Marignac. Twins : similar to those of albite. Cleavage: $O$ easy; $i-\imath \imath$ less so ; $I$ traces. Good crystals rare ; generally massive granular, and in grains clearable; sometimes cryptocrystalline or hornstone-like.
$\mathrm{H} .=6$. $\mathrm{G} .=2 \cdot 67-2 \cdot 76$. Lustre of O pearly, passing into vitreous; elsewhere vitreous or subresinons. Color gray, brown, or greenish, sometimes colorless and glassy; rarely porcelain-white; usually a change of colors in cleavable varieties. Streak uncolored. Translucent-subtranslucent.

[^41]in some colorless crystals; or pale; or deep; blue and green are the predominant colors; but yellow, rire-red, and pearl-gray also occur. By cutting very thin slices, parallel to $i$ - $\check{\imath}$, from the original labradorite, they are seen under the microscope to contain, besides striæ, great numbers of minute scales, like the aventurine oligoclase, which are probably göthite or hematite. These scales produce an aventurine effect which is quite independent of the play of colors which arises from the interference of the rays of light reflected by innumerable internal lameliæ (Reusch). The various forms of minerals (microplakites, microphyllites, etc.) enclosed in the labradorite, and their relation to it in position, have been thoroughly investigated by Schrauf (Ber. Ak., Wien, Dec., 1869).

Pyr, etc.-B.B. fuses at 3 to a cclorless glass. Decomposed with difficulty by hydrochloric acid generally leaving a portion of undecomposed mineral.

Oiv3.-Labradorite is a constituent of some rocks, both metamorphic and igneous; e.g., diabase, doleryte, basalt, etc. The labradoritic metamorphic rocks are most common among the formations of the Archæan or pre-Silurian era. Such are part of those of British America, northern New York, Pennsylvania, Arkansas; those of Greenland, Norway, Fınland, Sweden, and probably of the Vosges. Being a feldspar containjug comparatively little silica, it occurs mainly in rocks which include little or no quartz (free silica).

Kiew has furnished fine specimens; also Labrador. It is met with in many places in Canada East. Occurs at Essex Co., N. Y. ; also in St. Lawrence, Warren, Scoharie, and Green Cos. In Pennsylvania, at Mineral Hill, Chester Co. ; in the Witchita Mts., Arkansas, etc.

Labradorite was first bronght from the Isle of Paul, on the coast of Labrador, by Mr. Wolfe, a Moravian missionary, about the year 1770, and was called by the early mineralogists Labrador stone (Labrudorstein), and also chatoyant, opaline, or Labrador feldspar. Labradorite receives a fine polish, and owing to the chatoyant reflections, the specimens are often highly beantiful. It is sometimes used in jewelry.

Maskelynite.-Occurs in transparent, isometric, grains in the meteorite of Shergotty. Same composition as labradorite.

## ANDESITE. Andesine.

Triclinic. Approximate angles from Esterel crystals (DesCl.): $O \wedge i-\ell$, left, $87^{\circ}-88^{\circ}, \mathrm{O} \wedge I=111^{\circ}-112^{\circ}, O \wedge I=115^{\circ}, I \wedge i-\imath=119^{\circ}-120^{\circ}, I^{\prime} \wedge i-\imath$ $=120^{\circ}, O \wedge 2 \cdot \bar{i}=101^{\circ}-102^{\circ}$. Twins: resembling those of albite. Seldom in crystals. Cleavage more nneven than in albite. Also granular massive.
$1 \mathrm{~L},=5-6 . \quad \mathrm{G} .=2 \cdot 61-2 \cdot 74$. Color white, gray, greenish, yellowish, fleshred. Lustre subvitreous, inclining to pearly.

Comp.-Q. ratio 1:3:8, but varying to 1:3:7. General formula $R A 1 \operatorname{Si}_{4} \mathrm{O}_{12} ; \mathrm{R}=\mathrm{Na}_{2}$ and Ca in the ratio $1: 1$ to $3: 1$; if the ratio is $1: 1$, the formula corresponds to Silica $59 \cdot 8$, alumina $25 \cdot 5$, lime $7 \cdot 0$, soda $7 \cdot 7=100$.

Pyr., etc.-Andesite fuses in thin splinters before the blowpipe. Saccharite melts nnly on thin edges; with borax forms a clear glass. Imperfectly soluble in acids.

Obs.-Occurs in many rocks, especially some trachytes. The original locality was in the Andes, at Marmato ; also in the porphyry of l'Esterel, France ; in the Vosges Mts. ; at Vapnefiord, Iceland, in honey-yellow trausparent crystals, etc. In North America, found at Château Richer, Canada, forming with hypersthene and ilmenite a wide-spread rock; color flesh-red.

Andesite is regarded by DesCloizeaux as an altered oligoclase, but many careful analysen point to a feldspar having the composition given above.

## HYALOPHANE.

Monoclinic, like orthoclase, and angles nearly the same. $\quad C^{\gamma}=64^{\circ} 16^{\prime}$,「 $\wedge I=118^{\circ} 41^{\prime}, O \wedge 1-i=130^{\circ} 55 \frac{1}{2}^{\prime}$. Clearage: O perfect, $i-i$ somewhat less so. In small crystals, single, or in groups of two or three.
$\mathrm{H}=:=6-6.5$. G. $=2 \cdot 80$, transparent; 2.905, translucent. Lustre vitreous, or like that of adularia. Color white, or colorless; also flesh-red. Transparent to translucent.

Comp.-Q. ratio for $\mathrm{R}: \mathrm{R}: \mathrm{Si}=1: 3: 8$. Formula $\left(\mathrm{Ba}, \mathrm{K}_{2}\right) \mathrm{AlSi}_{4} \mathrm{O}_{12}$. Analysis of hyalophane from the Binnenthal by Stockar-Escher, $\mathrm{SiO}_{2} 52 \cdot 67, \mathrm{AlO}_{3} 21 \cdot 12, \mathrm{MgO} 0 \cdot 04, \mathrm{CaO} 0 \cdot 46$, $\mathrm{BaO} 15 \cdot 05, \mathrm{Na}_{2} \mathrm{O} 2 \cdot 14, \mathrm{~K}_{2} \mathrm{O} 7 \cdot 82, \mathrm{H}_{2} \mathrm{O} 0 \cdot 58=99 \cdot 88$.

Pyr., etc.-B.B. fuses with difficulty to a blebby glass. Unacted upon by acids.
Obs.-Occurs in a granular dolomite near Imfeld, in the Binnenthal, Switzerland ; also ut Jakobsberg in Sweden.

## OLIGOCLASE.

Triclinic. $I \wedge I^{\prime}=120^{\circ} 42^{\prime}, O \wedge i-\imath ้$, ov. $2-i^{\prime}=93^{\circ} 50^{\prime}, O \wedge I=110^{\circ} 55^{\prime}$, $0 \wedge I^{\prime}=114^{\circ} 40^{\prime}$. Cleavage: $O, i-\imath$ perfect, the datter least so. Twins: similar to those of albite. Also massive.
H. $=6-7 . \quad$ G. $=2 \cdot 56-2 \cdot 72$; mostly $2 \cdot 65-2 \cdot 69$. Lustre vitreo-pearly or waxy, to vitreous. Color usually whitish, with a faint tinge of grayishgreen, grayish-white, reddish-white, greenish, reddish; sometimes aventurine. Transparent, subtranslucent. Fracture conchoidal to uneven.

Comp., Var.--Q. ratio for $\mathrm{R}: \not \mathrm{Al}: \mathrm{Si}=1: 3: 9$, though with some variations (see p. 297). Formula $\mathrm{RH} \mathrm{HSi}_{1} \mathrm{O}_{14}$, with
 $\mathrm{R}=\mathrm{Na}_{2}\left(\mathrm{~K}_{2}\right), \mathrm{Ca}$ The ratio of 3:1 for $\mathrm{Na}: \mathrm{Ca}$ corresponds in this formula to Silica $61 \cdot 9$, alumina $24 \cdot 1$, lime $5 \cdot 2$, soda $8 \cdot 8=100$.

Var. 1. Cleavable ; in crystals or massive. 2. Compact massive ; oligoclase-felsite ; includea part, at least, of the so-called compact feldspar or felsite, consisting of the feldspar in a compact, either fine granular or flint-like state. 3. Aventurine oligochese, or sunstone. Color grayish-white to reddish-gray, usually the latter, with internal yellowish or reddish fire-like reflections proceeding from disseminated crystals of probably either hematite or göthite. 4. Moonstone pt. A whitish opalescence.

Pyr., etc.-B.B. fuses at 3.5 to a clear or enamel-like glass. Not materially acted upon by acide.

Obs.-Occurs in porphyry, granite, syenite, serpentine, and also in different eruptive rocks. It is sometimes associated with orthoclase in granite, or other granits-like rocks. Among its localities are Pargas in Finland ; Schaitansk, Ural; in protogine of the Mer-de-Glace, in the Alps; in fine crystals at Mt. Somma; as sunstone at Tvedestrand, Norway; in Iceland, colorless, at Hafnefjord (hufnefiordite). In the United States, at Unionville, Pa. ; also at Haddam, Ct. ; Mineral Hill, Delaware Co., Pan ; at the emery mine, Chester, Mass.

Named in 1826 by Breithaupt from $\dot{\lambda} \lambda i y o s$, little, and $\kappa \lambda a ́ \omega$, to cleave.
Tsciermakite (v. Kobell).-Supposed to be a magnesia-feldspar, but the conclusion was probably Dased on the analysis of impure material. Later investigations (Hawes, Pisani) make it an oligoclase. Occurs with kjerulfine from Bamle, Norway.

## ALBITE.*

XTriclinic. $I \wedge P_{=}=120^{\circ} 47^{\prime}, O \wedge i-乞=93^{\circ} 36^{\prime}, O \wedge I^{\prime}=114^{\circ} 42^{\prime}, O \wedge I$ $=110^{\circ} 50^{\prime}, O \wedge 2-\iota^{\prime}=136^{\circ} 50^{\prime}, O \wedge 2-\check{\imath}=133^{\circ} 14^{\prime}$. Clearage: $O$, $i-\imath$ perfect, the first most so; 1-i sometimes distinct. Twins: tivinning-plane $i-\zeta$, axis of revolution normal to $i-\zeta$, this is the most common method, and its repetition gives rise to the fine striations (p. 91) upon the plane $O$, which are so characteristic of the triclinic feldspars; twinning-plane, $2-\tau$ (f. 578)
analogous to the Baveno twins of orthoclase; also twinning-axis, the vertical axis (f. 575 ) ; twinning-axis, the macrodiagonal axis* (b), the pericline twins. Double twins not uncommon. True simple crystals very rare. Also mas.. sive, either lamellar or granular ; the laminæ sometimes divergent; granular varieties eccasionally quite fine to impalpable.

$\mathrm{H} .=6-7 . \quad \mathrm{G} .=2 \cdot 59-2 \cdot 65$. Lustre pearly upon a cleavage face ; vitreons in other directions. Color white, also occasionally bluish, gray, reddish, greenish, and green; sometimes having a bluish opalescence or play of colors on $O$. Streak uncolored. Transparent-subtranslucent. Fracture uneven. Brittle.

Comp., Var.-Q. ratio $\mathrm{Na}: \mathrm{Al}: \mathrm{Si}=1: 3: 12$. Formula $\mathrm{Na}_{2} \mathrm{AlSi}_{6} \mathrm{O}_{16}=$ Silica $68 \cdot 6$, alumina $19 \cdot 6$, soda $11 \cdot 8=100$. A small part of the sodium is replaced usually, if not always, by potassium, and also by calcium (here $\mathrm{Na}_{2}$ by Ca ). But these differences are not externally apparent.

Var. 1. Ordinary. (a) In crystals or cleavable massive. The angles vary somewhat, especially for plane 1'. (b) Aventurine; similar to aventurine oligoclase and orthoclase. (c) Moonstone ; similar to moonstone under oligoclase and orthoclase. Peristerite is a whitish adularia-like albite, slightly iridescent, having G. $=2 \cdot 626$; named from $\pi \varepsilon p \iota \sigma \tau \varepsilon \rho a ́, ~ p i g e o n, ~ t h e ~$ colors resembling somewhat those of the neck of a pigeon. (d) Pericline is in large, opaque, white crystals, short and broad, of the forms in f. 577 (f. 334, p. 101); from the chlorite schists of the Alps. Lamellar ; cleavelrandite, a white kind found at Chesterfield, Mass.
Pyr., etc.-B.B. fuses at 4 to a colorless or white glass, imparting an intense yellow to the flame. Not acted upon by acids.
Obs.-Albite is a constituent of several rocks, as dioryte, etc. It occurs with orthoclase in some granite. It is common also in gneiss, and sometimes in the crystalline schists. Veins of albitic granite are often repositories of the rarer granite minerals and of fine crystallizations of gems including beryl, tourmaline, allanite, columbite, etc. It occurs also in some "rachyte, in phonolyte, in granular limestone in disseminated crystals, as near Modane in Savoy. Some localities for crystals are: Schneeberg in Passeir, in simple crystals; Col du Bonhomme; St. Gothard, and elsewhere in the Alps; Penig, etc., Saxony ; Arendal; Greenland; Island of Elbr.

In the U. S., in Maine, at Paris. In Mass., at Chesterfield; at Goshen. In Conn., at Haddam; at Middletown. In N. York, at Granville, Washington Co. ; at Moriah, Essex Co. In Penn., at Unionville, Delaware Co.
The name Albite is derived from albus, white, in allusion to its color, and was given the species ky Gahn and Berselius in 1814.

[^42]
## ORTHOCLASE.

Moneclinic. $C^{\prime}=63^{\circ} 53^{\prime}, I \wedge I=118^{\circ} 48^{\prime}, O \wedge 1-\grave{\imath}=153^{\circ} 28^{\prime} ; c: b: a$ $=0.844: 1 \div 51 \varepsilon 3: 1$. $O \wedge 1-i=129^{\circ} 41^{\prime}, O \wedge 2-i=99^{\circ} 38^{\prime}, O \wedge 2=98^{\circ}$ $4^{\prime}$. Cleavage: $O$ perfect; $i$-i less distinct; $i-i$ faint; also imperfect in the direction of one of the faces $I$. Twins: twinning-plane, $i-i$ (Carlsbad twins) f. 582, but the clinopinacoid ( $i-i$ ) the composition-face (see p. 98); twinning-plane the base ( 0 ) f. 583; also the clinodome, 2-ì (Baveno twins), as in f . 588 , in which the prism is made up of two adjoining planes $O$ and two $i-\grave{\imath}$, and is nearly square, because $O \wedge i-i=90^{\circ}$, and $O \wedge 2-i=135^{\circ} 3^{\prime}$; $I \wedge I=169^{\circ} 28^{\prime}$; also the same in a twin of 4 crystals, f. 587, each side of the prism then an $O$ (see also p. 99). Often massive, granular ; sometimes lamellar. Also compact crypto-crystalline, and sometimes flint-like or jasper-like.

580


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583
 587


588



Loxoclase.
H. $=6-6 \cdot 5$. G. $=2 \cdot 44-2 \cdot 62$, mostly $2 \cdot 5-2 \cdot 6$. Lustre vitreous; on cleav-age-surface sometimes pearly. Color white, gray, flesh-red, common; greenish-white, bright-green. Streak uncolored. Transparent to translucent. Fracture conchoidal to uneven. Optic-axial plane sometimes in the orthodiagonal section and sometimes in the clinodiagonal ; acute bisectrix always negative, normal to the orthodiagonal.

Comp., Var.-Q. ratio for $\mathrm{K}: \mathrm{Al}: \mathrm{Si}=1: 3: 12$. Formula $\mathrm{K}_{2} \mathrm{AlSi}_{6} \mathrm{O}_{16}=$ Silica $64 \cdot 7$, alumina $18 \cdot 4$, potash $16 \cdot 9=100$; with sodium sometimes replacing part of the potassium. The orthoclase of Carlsbad contains rubidium. The varieties depend mainly on structure, variations in angles, the presence of soda, and the presence of impurities.

The amount of sodium detected by analyses varies greatly, the variety sanidin (see below) sometimes containing 6 per cent. The variations in angles are large, and they occur sometimes even in specimens of the same locality. The crystallization is normally monoclinic, and the variations are simply irregularities. There are also large optical variations in orthoclase, on which see DesCl. Min., i., 329.

Var. 1. Ordinary. In crystals, or cleavable massive. Adularia (adular). Transparent, oleavable, usually with pearly opalescent reflections, and sometimes with a play of colors like labradorite, thongh paler in shade. Moonstone belongs in part here, the rest being albite and oligoclase. Sunstone, or aventurine feldspar: In part ortboclase, rest albite or oligoclase (q. 『.). Amazonstone: Bright verdigris green, and cleavable, mostly mixtures of orthoclase and microcline (Dx.). Kœnig concludes that the coloring matter of the Pike's Peak amazonstone is an organic compound of iron, which has been infilirated into the mass.

Sanilin of Nose, or glassy feldspar (including much of the lce-spar, part of which is anow
thite). Occurs in transparent glassy crystals, mostly tabular (whence the name from $\sigma a \bar{v} \iota \varsigma$, a board), in lava, pamice, trachyte, phonolite, etc. Proportion of soda to potash varies from 1:20 to 2:1. Rhyacolite is the same; the name was applied to glassy crystals from Mt. Somma (Eisspath, Wern.).

Chesterlite. In white crystals, smooth, but feebly lustrous. implanted on dolomite in Ches. ter Co., Penn., and having wide variations in its angles. It contains but little soda. According to DesCloizeaux the chesterlite consists of a union of parallel bands of orthoclase and a triclinic feldspar of the same composition, which he calls microcline (see below).

Loxoclase. In grayish-white or yellowish crystals, a little pearly or greasy in lustre, often large, feebly shining, lengthened usually in the direction of the clinodiagonal. $O \wedge I=112$ $30^{\prime}, O \wedge I^{\prime}=112^{\circ} 50^{\prime}, I \wedge I^{\prime}=120^{\circ} 20^{\prime}, O \wedge i-i$ (cleavage angle) $=90^{\circ}$, Breith. G. $=2 \cdot 6-2 \cdot 62$, Plattner. The analyses find much more soda than potash, the ratio being about $3: 1$, but how far this is due to mixture with albite has not been ascertained. From Hammond, St Lawrence Co., N. Y. Named from nogó, transverse, añd $\kappa \lambda \dot{\alpha} \omega, I$ cleave, under the idea that the crystals are peculiar in having cleavage parallel to the orthodiagonal section. Perthite. A flesh-red aventurine feldspar, consisting of interlaminated albite and orthoclase, as shown by Breithaupt. From Perth, Canada East.

Compact Orthoclase or Orthoclase-felsite.-This crypto-crystalline variety is common and occurs of various colors, from white and brown to deep red. There are two kinds (a) the jasper-like, with a subvitreous lustre; and (b) the ceratoid or voax-like, with a waxy lustre. Some red kinds look closely like red jasper, but are easily distinguished by the fusibility. The orthoclase differs from the albite felsite in containing much more potash than soda. The Swedish name Hälleflinta means false fint.

Pyr., etc.-B.B. fuses at 5; varieties containing much soda are more fusible. Loxoclase fuses at 4. Not acted upon by acids.

Obs.-Orthoclase is an essential constituent of many rocks; here are included granite, gneiss, and mica schist; also syenite, trachyte, phonolyte, etc., etc.

Fine crystals are found at Carlsbad in Bohemia; Katherinenburg, Siberia; Arendal, Norway; Baveno in Piedmont; in Cornwall; in the Urals: the Mourne mountains, Ireland, etc.; in the trachyte of the Drachenfels on the Rhine. In the U. States. orthoclase is found in N. Hamp., at Acworth. In Conn., at Haddam and Middletown. • In N. York, at Rossie; in the town of Hammond; in Lewis Co.; near Natural Bridge ; in Warwick; and at Amity and Edenville. In Penn., in crystals at Leiperville, Delaware Co., etc. In N. Car., at Washington Mine, Davidson Co.; beautiful Amazoustone at Pike's Peak, Col. Massive orthoclase is abundant at many localities.

Microcline.* A triclinic potash feldspar.-The name microcline was originally given by Breithaupt to a whitish or reddish feldspar from the zircon-syenite of Fredericksvärn and Brevig, Norway, on the ground that it was triclinic. It was shown by DesCloizeaux that this feldspar was merely a variety of orthoclase remarkable for its large amount of soda. Recently the latter author has proposed to retain this name for a feldspar found in the midst of granites, pegmatite, and gneiss, which is shown both by the angle between its cleavage planes, and also by its optical properties, to be really triclinic.

Form generally like that of orthoclase. Cleavage basal anū clinodiagonal, and also easy parallel to both prismatic faces ( 1 and $I^{\prime}$ ); for the optical properties see p. 298. Often associated with orthoclase in regular parallel bands, especially in the amazonstone; albite is also sometimes present, though irregularly. Analysis of a "pure microcling" from Magnet Cove by Pisani. G. $=2 \cdot 54$.

| $\mathrm{SiO}_{2}$ | $\mathrm{AlO}_{3}$ | $\underset{\mathrm{AlOO}}{3}$ | $\mathrm{FeO}_{2} \mathrm{O}$ | $\mathrm{Na}_{2} \mathrm{O}$ | ign. |
| :---: | :---: | :---: | :---: | :---: | :---: |
| $64 \cdot 30$ | $19 \cdot 70$ | 0.74 | $15 \cdot 60$ | $0 \cdot 48$ | $0 \cdot 35=101 \cdot 17$ |

The association of orthoclase and microcline was observed in specimens from the Ilmen Mts. ; Urals ; Arendal ; Greenland; Labrador; Leverett, Mass.; Delaware, Chester Co., Penn.; Pike's Peak, Col. The purest microcline was that of a greenish color from Magnet Cove, Ark. ; it enclosed crystals of ægivite, and was not mixed with orthoclase.

Subsilicates.
Humite or Chondrodite Group, including three sub-species:

## I. Humite ; II. Chondrodite ; III. Clinohumite.

The existence of three types of forms among the crystals of humite (Vesuvius) wos sarly shown by Scacchi; they have since then been further investigated by vom Rath (Pogg. Erg.,

Bd. v., 321, 1871 ; ibid., vi., 385, 1873). The chemical identity of the species humite and chondrodite was shown by Rammelsberg ; later Kokscharof proved that the crystals of chondrodite from Pargas, Finland, were identical in form and angles with Scacchi's type II, of humite, and the same has also been shown of the Swedish crystals by vom Rath. In 1875 the author described crystals of chondrodite from Brewster, N. Y., belonging to each of the three types of humite; he showed, moreover, then and later (Feb., 1876), that contrary to what had been previously assumed, the crystals of both type II. and type III. were monoclinic, not orthorhominic. DesCloizeaux and Klein have since proved (Jahrb. Min., 1876, No. 6) the mouoclinic character of type III. of the Vesuvian humite, and the former that of thr Swedish crystals (type II.) ; he, moreover, proved the orthorhombic character of the crystaln of type I., Vesuvius. In accordance with these facts DesCloizeaux has proposed that the thre" types be regarded as distinct species, with the names given above.
I. HUMITE.* Including type I., Scacchi, Vesuvius. Also rare crystals from Brewster, N. Y. The latter large, coarse, and having suffered more or less alteration.

Orthorhombic. Holohedral. $i-\bar{\Sigma}\left(o^{2}\right) \wedge i \bar{\Sigma}=130^{\circ} 19^{\prime} ; O(A) \wedge 3-\bar{i}\left(i^{3}\right)=$ $102^{\circ} 48^{\prime} ; O \wedge 1-\bar{\imath}\left(i^{2}\right)=124^{\circ} 16^{\prime} ; O \wedge 3-\grave{\imath}\left(e^{5}\right)=103^{\circ} 47^{\prime} ; O \wedge 1-亡\left(\epsilon^{3}\right)=126^{\circ}$ $21^{\prime} ; O \wedge 1 \cdot \frac{2}{2}\left(r^{3}\right)=121^{\circ} 44^{\prime}$. 'Twins: twinning-plane $\frac{9}{7}-\tau$, also $\frac{3}{7}-\tau$, in both cases the angle of the horizontal prism is nearly $120^{\circ}$. Optic-axial plane parallel to the base, acute bisectrix positive, normal to $i-i$. Dispersion almost zero. $2 \mathrm{H} a=78^{\circ} 18^{\prime}-79^{\circ}$ for red rays. ( DesCl .)

II. CHONDRODITE.* Including type II. of Scacchi, Vesuvius ; also crystals from Finland, Sweden, and with few exceptions those of Brewster, N. Y.

Monoclinic. $A \wedge i=122^{\circ} 29^{\prime} ; A \wedge e^{2}=109^{\circ} 5^{\prime} ; A \wedge e^{2 \prime}=108^{\circ} 58^{\prime}$; $A: n^{2}=103^{\circ} 12^{\prime} ; A \wedge n^{2 \prime}=103^{\circ} 9^{\prime} ; A \wedge r^{1}=135^{\circ} 20^{\prime} ; A \wedge r^{2}=125^{\circ}$ $50^{\prime} ; C \wedge r^{3}=146^{\circ} 24^{\prime} ; C \wedge n^{2}=135^{\circ} 40^{\prime}: C \wedge n^{2 \prime}=135^{\circ} 41^{\prime}$.

The letters (those employed by Scacchi) correspond to the following syinbols:--
$\begin{array}{lllll}A=0 & i=1-i & e^{2}=-2-i & n^{2}=-2 & r^{2}=-4-2\end{array} r^{3}=-\frac{4}{4}-2 \quad m^{2}=-6-\frac{3}{3}$.
Twins: twinnirg plane $\frac{2}{5} i\left( \pm\right.$ ? ) and $\frac{8}{8} i( \pm$ ?), (both having a prismatic angle nearly $120^{\circ}$ ); also the basal plane $O$ (Brewster, N. Y., f. 593).

Optic-axial plane makes an angle of $26^{\circ}$ with the base; acute bisectrix
msitive, normal to the clinopinacoid ( $C$ ) . $2 \mathrm{H} a=88^{\circ} 48^{\prime}$ for red rays, Drewster, N. Y. (E. S. D.). $2 \mathrm{H} a=86^{\circ} 14^{\prime}-87^{\circ} 20^{\prime}$ (red rays), Sweden, (DesCl.)

The above angles are those given by DesCloizeaux, the author's own measurements on the crystals from Brewster (not yet completed), point to a smaller variation from the rectangular type. DesCloizeanx makes the plane $e^{2 \prime}=i-i$, and $r^{4}=I, r^{2}=1, r^{3}=-1$.

III. CLINOHUMITE. Including type III. of Scacchi, Vesuvius; also rare finely polished red crystals from Brewster, N. Y.

Monoclinic. $A \wedge e^{2}=133^{\circ} 40^{\prime} ; A \wedge e^{2 \prime}=133^{\circ} 40^{\prime} ; A \wedge \imath^{2}=125^{\circ} 13^{\prime}$; $A \wedge m=114^{\circ} 55^{\prime} ; A \wedge m^{2}=92^{\circ} 58^{\prime} ; A \wedge n=132^{\circ} 14^{\prime} ; A \wedge n^{2}=122^{\circ}$ $57^{\prime} ; A \wedge n^{4}=97^{\circ} 23^{\prime} ; A \wedge n^{4 \prime}=97^{\circ} 23^{\prime} ; A \wedge r^{3}=131^{\circ} 23 ; A \wedge r^{4}=125^{\circ}$ $4 i^{\prime} ; C \wedge r^{3}=132^{\circ} 56^{\prime} ; C \wedge r^{4}=137^{\circ} 25^{\prime}$. DesCloizeaux.

These letters (those employed by Scacchi) correspond to the following symbols:-

$$
\begin{array}{lllllll}
A=O & i=\frac{3}{3} i & n=\frac{4}{0} & n^{4}=-4 & r^{3}=-\frac{8}{11}-2 & r^{5}=-\frac{8}{2}-2 & r^{7}=-\frac{8}{3}-2 \\
C=i-i & i^{2}=1-i & n^{2}=-\frac{4}{5} & n^{4}=4 & r^{4}= & \frac{8}{9}-2 & r^{6}=\frac{8}{8}-2
\end{array} r^{8}=8-\frac{1}{8}
$$

DesCloizeaux makes the plane $e^{4}=i-i, r^{8}=I$, and $r^{4}=-1$, and $r^{5}=1$. Twins: twinning-plane $-\frac{4}{3} i$; also the basal plane (Brewster). Optic-axial plane makes an angle of $7 \frac{1}{2}^{\circ}$ with the base, Brewster (Dana) ; same angle for Vesuvian crystals equals $12^{\circ} 28^{\prime}$ (Klein), about $11^{\circ}$ (DesCl.). Acute bisectrix positive, normal to clinopinacoid. $2 \mathrm{H} a=84^{\circ} 40^{\prime}-85^{\circ} 15^{\prime}$, yellow (Kl.). $=84^{\circ} 38^{\prime}-85^{\circ} 4^{\prime}$ white crystals, and $=86^{\circ} 40^{\prime}-87^{\circ} 14^{\prime}$ brown crystals (DesCl.). Sections of crystals often shows a complex twinned structure.

In other physical and in chemical characters these three sub-species are hardly to be distinguished.
H. $=6-6 \cdot 5 . \quad$ G. $=3 \cdot 118-3 \cdot 24$. Lustre vitreons-resinons. Color of crystals yellowish-white, citron-yellow, honey-yellow, hyacinth-red, brownish (Vesuvius); also deep garnet-red (Brewster). Color of the mineral occurring massive and in rounded imbedded grains (chondrodite at least in part) as of crystals, also sometimes olive-green, apple-green, gray, black. Streak white, or slightly yellowish, or grayish. Transparent-subtranslucent. Fracture subconchoidal-uneven.

Comp.-The chemical investigations of Rammelsberg and vom Rath have served to show a considerable variation in composition in the different varieties, but do not give decidedly different formulas to the three types of Scacchi, that is, the three minerals described above.

In general Q . ratio for $\mathrm{Mg}: \mathrm{Si}=4: 3\left(1 \frac{1}{3}: 1\right)$, and the formula then $\mathrm{Mg}_{8} \mathrm{Si}_{3} \mathrm{O}_{14}$; or, as preferred by Rammelsberg, $\mathrm{Mg}: \mathrm{Si}=5: 4\left(1 \frac{1}{2}: 1\right)$, and the formula is then $\mathrm{Mg}_{5} \mathrm{Si}_{2} \mathrm{O}_{9}$. In all cases part of the magnesium is replaced by iron, and part of the oxygen by fluorine ( $\mathrm{F}_{2}$ ), the amount varying from $2 \frac{1}{2}$ to $8 \&$ p. c., but certainly not dependent (v. Rath and Ramm.) upon the three types.
Anclyses:-
I. Humite, Vesuvius,
II. Chondrodite, Vesuvius,
II. Chondrodite, Brewster,
II. Chondrodite, Sweden,
III. Clinohumite, Vesuvius,

| $\mathrm{SiO}_{2}$ | FeO | MgO | F |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: |
| 35.63 | $5 \cdot 12$ | $54 \cdot 45$ | $2 \cdot 43$ | $\cdot \mathrm{CaO} 0 \cdot 23$ | $\mathrm{AlO}_{3} 0 \cdot 82=99 \cdot 68$, v. Rath. |
| $33 \cdot 26$ | $2 \cdot 30$ | 57.92 | $5 \cdot 4$ | CaO 0.74 | $\mathrm{AlO}_{3} 1 \cdot 06=100 \cdot 32$, Ramm. |
| $34 \cdot 10$ | $7 \cdot 28$ | 53.\%2 | $4 \cdot 14$ |  | $\mathrm{AlO}_{3} 0 \cdot 48=99 \cdot 72$, Hawes. |
| $33 \cdot 96$ | $6 \cdot 83$ | 53.51 | 4.24 |  | $\mathrm{AlO}_{3} 0 \cdot 72=99 \cdot 26$, v. Rath. |
| 36.82 | $5 \cdot 48$ | 54.92 | $2 \cdot 40$ |  | $\mathrm{HlO}_{3} 0.24=99 \cdot 86$, v. Rath. |
| , 33.97 | $3 \cdot 48$ | 56.97 | $7 \cdot 44$ |  | $=101 \cdot 68$, Ramm. |

Pyr., etc.-B.B. infusible; some varieties blacken and then burn white. Fused with salt of phosphorus in the open tube gives a reaction for fluorine. With the fluxes a reaction for iron. Gelatinizes with acids. Heated with sulphuric acid gives off silicon fluoride.
Diff.-Distinguishing characters are: infusibility; gelatinizing with acids; fluorine reaction with sulphuric acid.
Obs.-The localities of the crystallized minerals have already been mentioned.
The granular chondrodite (?) occurs mostly in limestone. It is found in Finland and in Sweden; at Taberg in Wermland; at Boden in Saxony; on Loch Ness in Scotland; at Achmatovsk in the Ural, etc. Abundant in the counties of Sussex. N. J., and Orange, N. Y., where it is associated with spinel. In N. Jersey, at Bryam ; at Sparta; at Vernon, Lockwood, and Franklin. In $N$. York, in Orange Co., in Warwick, Monroe, etc. ; near Edenville; at the Tilly Foster Iron Mine, Brewster, Putnam Co. In Mass., at Chelmsford. In Penn., near Chadsford. In C'anada, in limestone at St. Crosby ; St. Jerome; St. Adèle; Grenville, etc., abundant
tourmainine.* Turmalin, Germ.
Rhombohedral. $R \wedge R=103^{\circ}, O \wedge R=134^{\circ} 3^{\prime} ; \dot{c}=0.89526$. $\frac{1}{4} \wedge \frac{1}{4}=$

hemihedral, being often unlike at the opposite extremities, or hemimorphic, and the prisms often triangular. Cleavage: $R,-\frac{1}{2}$. and $i-2$, difficult. Sometimes massive compact; also columnar, coarse or fine, parallel or divergent.
$\mathrm{H} .=7-7.5 . \quad \mathrm{G} .=2 \cdot 94-3.3 . \quad$ Lustre vitreous. Color black, brownishblack, bluish-black, most common ; blue, green, red, and sometimes of rich shades; rarely white or colorless; some specimens red internally and green externally; and others red at one extremity, and green, blue, or black at the other. Dichroic (p. 165). Streak uncolored. Transparent-opaque; greater transparency across the prism than in the line of the axis. Fracture subconchoidal-uneven. Brittle. Pyroelectric (p. 169).

Var.-1. Ordinary. In crystals. (a) Rubellite; the red sometimes transparent. (b) Indicolite; the blue, either pale or bluish-black ; named from the indigo-blue color. (c) Brazilian Sapphire (in jewelry); Berlin-blue and transparent; (d) Brazilian Emerald, Chrysolite (or Peridot) of Brazil; green and transparent. (e) Peridot of Ceylon; honey-yellow. (f) Achroite; colorless tourmaline, from Elba. (g) Aphrizite; black tourmaline, from Krageröe, Norway. ( $h$ ) Columnar and black; coarse columnar. Resembles somewhat ho:nblende, but nas a more resinous fracture, and is without distinct cleavage or anything like a fibrous appearance in the texture.

Comp.-Q. ratio of all varieties for $\mathrm{R}: \mathrm{Si}=3: 2$ (Rammelsberg), consequently the general formula is $\stackrel{11}{R}_{\mathrm{R}_{3}}(\stackrel{\mathrm{I}}{\mathrm{R}}, \mathrm{R}) \mathrm{SiO}_{5} . \stackrel{1}{\mathrm{R}}$ may represent here $\mathrm{H}, \mathrm{K}, \mathrm{Na}, \mathrm{Li}$; also $\stackrel{11}{\mathrm{R}}=\mathrm{Mg}(\mathrm{Ca}), \mathrm{Fe}, \mathrm{Mn}$, and $\mathrm{R}=\mathrm{Al}, \mathrm{B}_{2}$; further than this the Si is often in part replaced by $\mathrm{F}_{2}$. Rammelsberg distinguishes two groups, where the Q . ratio for $\mathrm{B}: \mathrm{Al}: \mathrm{Si}=3: 6: 8$, and (2) with the Q . ratio for B:Al: $\mathrm{Si}=1: 3: 3$. In the first group fall most of the yellow, brown, and black varieties, the bivalent elements ( $\mathrm{Mg}, \mathrm{Fe}$ ) predominating, the general formula being ${ }_{\mathrm{R}}^{\mathrm{R}}\left(\frac{\mathrm{I}}{\mathrm{R}_{6}}\right) \mathrm{R}_{9} \mathrm{Si}_{4} \mathrm{O}_{20}$. The second group includes the colorless, red, and slightly green kinds, the univalent elements appearing most prominent, especially lithium. The general formula is $\mathrm{R}_{6}\left(\mathrm{R}_{3}\right) \mathrm{R}_{8} \mathrm{Si}_{9} \mathrm{O}_{45}$.

Several distinct varieties are made under these groups, which will be sufficiently illustrated by the following analyses, by Rammelsberg. I. Gouverneur, brown; G. $=3 \cdot 049$. II. Haddam, black; G. $=3 \cdot 136$. III. Goshen, bluish-black; G. $=3 \cdot 203$. IV. Paris, Me., red; G. $=3 \cdot 019$. V. Chesterfield, Mass., green; G. $=3 \cdot 069$.

|  | ${ }_{2}$ | $\mathrm{B}_{2} \mathrm{O}$ | AlO | FeO | Mn | Mg | , | Na | - | $\mathrm{Li}_{2} \mathrm{O}$ | F | , |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | 85 | (8.35) | 31 | $1 \cdot 14$ |  | 14.89 | $1 \cdot 6$ | $1 \cdot 28$ | $0 \cdot 26$ |  |  | .31 |
| II. | 37.50 | (9.02) | $30 \cdot 87$ | $8 \cdot 54$ |  | $8 \cdot 60$ | $1 \cdot 33$ | $1 \cdot 60$ | 3 |  |  | $\cdot 81=100 \cdot 00$ |
| III. | 36.22 | 10.65 | $33 \cdot 35$ | 11.95 | $1 \cdot 25$ | $0 \cdot 63$ |  | 1.75 | $0 \cdot 40$ | 0.84 | 82 | $2 \cdot 21=100 \cdot 82$ |
| IV. | 19 | $9 \cdot 97$ | 42.63 |  | . 94 | $0 \cdot 39$ | $0 \cdot 45$ | $2 \cdot 60$ | $0 \cdot 68$ | $1 \cdot 17$ | $1 \cdot 18$ | $2 \cdot 00=100 \cdot 20$ |
|  | $38 \cdot 46$ | $9 \cdot 7$ | 36 | $6 \cdot 38$ | 0.78 | 1.88 |  | $2 \cdot 47$ | $0 \cdot 47$ | 0.72 | 0.55 | 2.31 |

Pyr., etc.-I. fuse rather easily to a white blebby glass or slag ; II. fuse with a strong heat to a blebby slag or enamel ; III. fuse with difficulty, or, in some, only on the edges; IV. fuse on the edges, and often with great difficulty, and some are infusible; V. infusible, but becoming white or paler. With the fluxes many varieties give reactions for iron and manganese. Fused with a mixture of potassium bisulphate and fluorite gives a strong reaction for boracic acid. By heat alone tourmaline loses weight from the evolution of silicon fluoride and perhaps also boron fluoride; and only after previous ignition is the mineral completely decomposed by fluohydric acid. Not decomposed by acids (Ramm.). After fusion perfectly decomposed by sulphuric acid (v. Kobell).

Diff.-Distinguished by its form, occurring commonly in three-sided, or six-sided prisms; absence of cleavage (unlike hornblende). It is less easily fusible than garnet or vesuvianite. B.B. (see above) gives a green flame (boron).

Obs.-Tourmaline is usually found in granite, gneiss, syenite, mica, chloritic or talcose schist, dolomite, granular limestone, and sometimes in sandstone near dykes of igneous rocks. The variety in granular limestone or dolomite is commonly brown.

Prominent localities are Katherinenburg in Siberia; Elba; Windisch Kappell in Carinthia ; Rozena; Airolo, Switzerland; St. Gothard. In Great Britain. Bovey Tracey in Devon; Cornwall, at different localities; Aberdeen in Scotland, etc.
In the U. States, in Maine, at Paris and Hebron. In Mass., at Chesterfield; at Goshen, biue. In N. Hamp., Grafton ; Acworth, etc. In Conn.. at Monroe and Haddam, black. In N. York,
near Gourerneur ; near Port Henry, Essex Co., enclosing orthoclase (see p. 109); Pierrepont; near Edenville. In Penn., near Unionville; at Chester; Middletown, and elsewhere. In Canada, at G. Calumet Id. ; at Fitzroy, C.W.; at Hunterstown, C. E. ; at Bathurst anc Elmsley, C. W.

Gehienite.-Tetragonal. Color grayish-green. Q. ratio for $\mathrm{R}: \mathrm{R}: \mathrm{Si}=3: 3: 4$, or $3:$ : for bases and silicon. Formula $\mathrm{Ca}_{3} \mathrm{RSi}_{2} \mathrm{O}_{10}$, with $\mathrm{R}=\mathrm{Al}: \mp \mathrm{Fe}=5: 1$; this requires Silica $29 \cdot 9$, slumina $21 \cdot 5$, iron sesquioxide $6 \cdot 6$. lime $4^{\circ} 20=100$. Mt. Monzoni, Fassathal, Tyrol.

## ANDALUSITE.

Orthorhombic. $I \wedge I=90^{\circ} 48^{\prime}, O \wedge 1-\bar{\imath}=144^{\circ} 32^{\prime} ; c \cdot \bar{c} \bar{b}: \breve{a}=0.71241$ : $1 \cdot 01405: 1$. Cleavage : $I$ perfect in crystals from Brazil ; $i-\bar{\imath}$ less perfect; $i \cdot \imath$ in traces. Massive, imperfectly colnunar, sometimes radiated, and granular. $H .=7.5$; in some opaque kinds $3-6$. G. $=3.05-$ $3 \cdot 35$, mostly $3 \cdot 1-3 \cdot 2$. Lustre vitreons; often weak. Color whitish, rose-red, flesh-red, violet, pearl-gray, reddish-brown, olive-green. Streak uncolored. Transparent to opaque, usually subtranslucent. Fracture uneven, subconchoidal.

Var.-1. Ordinary. $H .=7 \cdot 5$ on the basal face, if not elsewhere. 2. Chiastolite (macle), Sterling, Mass. Stout crystals having the axis and angles of a different color from the rest, owing to a regular ar:angement of impurities through the interior, and hence exhiticing a colored cross, or a tesselated appearance in a transverse section. H. $=3-7 \cdot 5$, varying much with the degree of impurity.
 The following figure shows sections of some crystals (see also p. 110).

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Comp.-Q. ratio for $\mathrm{R}: \mathrm{Si}=3: 2 ; \mathrm{AlSiO}_{5}=$ Silica $36 \cdot 9$, alumina $63 \cdot 1=100$. Sometimes a little $\mathrm{FeO}_{3}$ is present.
Pyr., etc.-B.B. infusible. With cobalt solution gives a blue color. Not decomposed by acids. Decomposed on fusion with caustic alkalies and alkaline carbonates.

Diff.-Distinguishing characters : infusibility; harduess; and the form, being neariy that of a square prism, unlike staurolite.

Obs.-Most common in argillaceous schist, or other schists imperfectly crystalline; also in gneiss, mica schist, and related rocks. Found in Spain, in Andalusia, and thence the name of the species; in the Tyrol, Lisens valleyं; in Saxony, at Bräunsdorf, and elsewhere. In Ireland. In Brazil, province of Minas Geraes (transparent). Common in crystalline rocks of New England and Canada; good crystals have been obtained in Delaware Co., Penn., etc.• also in California; in Mass., at Sterling (chiastolite).

FIBROLITE. Bucholzite, Sillimanite.
Orthorhombic. $I \wedge I=96^{\circ}$ to $95^{\circ}$ in the smoothest crystals; usually large, the faces $I$ striated, and passing into $i-\bar{z}$. Cleavage : $i-\bar{i}$ very perfect, brilliant. Crystals commonly long and slender. Also fibrous or columnar massive, sometimes radiating.
H. $=6-7$. G. $=3 \cdot 2-3 \cdot 3$. Lustre vitreous, approaching subadamantive Color hair-brown, grayish-brown, grayish-white, grayish-green, pale olivegreen. Streak uncolored. Transparent to translucent.

Var.-1. Sillimanite. In long, slender crystals, passing into fibrous, with the fibres separable. 2. Fibrolite. Fibrous or fine columnar, firm and compact, sometimes radiated ; gray-ish-white to pale brown, and pale olive-green or greenish-gray. Bucholzite and monrolite are bere included; the latter is radiated columnar, and of the greenish color mentioned.

Comp.-AㄱSiO ${ }_{5}$, as for andalusite $=$ Silica $36 \cdot 9$, alumina $63 \cdot 1=100$.
Pyr., etc.-Same as given under andalusite.
Diff.-Distinguished from tremolite by its infusibility; also by its brilliant diagonal cleav. age, in which and in its specific gravity it differs from cyanite.

Obs.-Occurs in gneiss, mica schist, and related metamorphic rocks. In the Fassathal, Tyrol (bucholzite) ; at Bodenmais in Bavaria, etc. In the United States, at Worcester, Mass. Near Norwich, Conn.; at Chester, near Saybrook (sillimanite). In N. York, in Monroe, Orange Co. (monrolite). In Penn., at Chester on the Delaware; in Delaware Co., etc. In Delazoare, at Brandywine Springs. In N. Carolina, with corundum.

Fibrolite was much used for stone implements in western Europe in the "Stone age."
Wörthite, a hydrous fibrolite; Westanite (Sweden) is related in composition.

## CYANITE.* Kyanite. Disthene.

Triclinic. In flattened prisms ; $O$ rarely observed. Crystals oblong, usually very long and blade-like. Cleavage : $i-\bar{i}$ distinct ; $i-\imath$ less so ; $O$ imperfect. Also coarsely bladed columnar to subfibrous.
$\mathrm{H} .=5-7 \cdot 25$, the least on the lateral planes. G. $=3 \cdot 45-3 \cdot 7$. Lustre vit-reous-pearly. Color blue, white, blue along the centre of the blades or erystals with white margins; also gray, green, black. Streak uncolored. Translucent-transparent.

Var.-The white cyanite is sometimes called Rhoetizite.
Comp.-Al $\mathrm{SiO}_{5}=$ Silica $36 \cdot 9$, alumina $63 \cdot 1=100$, like andalusite and fibrolite.
Pyr., etc.-Same as for andalusite.
Diff,-Unlike the amphibole group of minerals in its infusibility ; occurrence in thin-bladed prisms characteristic.
Obs.-Occurs principally in gneiss and mica slate. Found at St. Gothard in Switzerland ; at Greiner and Pfitsch in the Tyrol; also in Styria; Carinthia; Bohemia. In Mass., at Chesterfield, etc. In Conn., at Litchfield; at Oxford. In Vermont, at Thetford. In Penn., in Chester Co.; and Delaware Co. In N. Carolina.

## TMPAZ.*

Orthorhombic. $I \wedge I=124^{\circ} 17^{\prime}, O \wedge 1-i=138^{\circ} 3^{\prime} ; \dot{c}: \bar{b}: \check{a}=0 \cdot 90243$ $: 1 \cdot 8920: 1 \quad 0 \wedge 1=134^{\circ} 25^{\prime}, 1 \wedge 1$, macr.,$=141^{\circ} 0^{\prime}$. Crystals usually hemihedra, the extremities being unlike; habit prismatic. Clearage: basal, highly perfect. Also firin columnar; also granular, coarse or fine.
$\mathrm{H} .=8$. G. $=3 \cdot 4-3.65$. Lustre vitreons. Color straw-yellow, wineyellow, white, grayish, greenish, bluish, reddish; pale. Streak uncolored. Transparent-subtranslucent. Fracture subconchoidal, uneven. Pyro-
electric. Optic-axial plane $i-\imath$; divergence very variable, sometimes differing much in different parts of the same crystal ; bisectrix positive, normal to 0 .


Comp.- $\mathrm{AlSiO}_{5}$, with part of the oxygen replaced by fluorine $\left(\mathrm{F}_{2}\right)$; ratio of $\mathrm{F}_{2}: 0=1: 5=$ Silicon $15 \cdot 17$, aluminum $29 \cdot 58$, oxygen $34 \cdot 67$, fluorine $20 \cdot 58=100$.
Pyr., etc.-B.B. infusible. Some varieties take a wine-yellow or pink tinge when heated. Fused in the open tube with salt of phosphorus gives the reaction for fluorine. With cobalt solution the pulverized mineral gives a fine blue on heating. Only partially attacked by sulphuric acid.

Diff.-Distinguishing characters:-hardness, greater than that of quartz; infusibility; perfect basal cleavage. B. B. yields fluorine.

Obs.-Topaz occurs in gneiss or granite, with tourmaline, mica, and beryl, occasionally with apatite, fluorite, and tin ore; also in talcose rock, as in Brazil, with euclase, etc., or in mica slate. Fine topazes come from the Urals; Kamschatka; Brazil; in Cairngorm, Aberdeenshire; at the tin mines of Bohemia and Saxony. Physalite (a coarse variety), occurs at Fossum, Norway; also in Durango, Mexico; at La Paz, province of Guanaxuato. In the United States, in Conn., at Trumbull. In N. Car., at Crowder's Mountain. In Utah, in Thomss's Mts. ; from gold washings of Oregon.

## EUCLASE.*

Monoclinic. $\quad C=79^{\circ} 44^{\prime}=0 \wedge i-i, I \wedge T=115^{\circ} 0^{\prime}, O \wedge 1-\imath=146^{\circ} 45^{\prime}$; $\dot{c}: \bar{b}: a \grave{a}=1 \cdot 02943: 1 \cdot 5446: 1=1: 1 \cdot 50043: 0 \cdot 97135$. Cleavage: $i-i$ very perfect and brilliant; $O, i-i$ much less distinct. Found only in crystals.
$\mathrm{H} .=7.5$. G. $=3.098$ (Haid.). Lustre vitreous, somewhat pearly on the cleavage-face. Colorless, pale moun-tain-green, passing into blue and white. Streak uncolored. Transparent; occasionally subtransparent. Fracture conchoidal. Very brittle.

[^43]DATOLITE. Humboldtite.
Monoclinic. $C=89^{\circ} 54^{\prime}=O$ (below) $\wedge i-i, I \wedge I=115^{\circ} 3^{\prime}, O \wedge 1-\grave{\imath}=$ $162^{\circ} 27^{\prime} ; \dot{c}: b: a ̀=049695: 1 \cdot 5712: 1$. $O \wedge-2-i=135^{\circ} 13^{\prime}, 0 \wedge 1=$ $149^{\circ} 33^{\prime}, I \wedge I$ front $=115^{\circ} 3^{\prime}, 2-i \wedge \wedge 2-i$, ov. $O,=115^{\circ} 21^{\prime}, i-2 \wedge i-2$, ov. $i-i_{s}$ $=76^{\circ} 18^{\prime}, 4-i \wedge 4-i$, ov. $O,=76^{\circ} 88$. Cleavage: $O$ distinct. Also botryoidal and globular, having a columnar structure ; also divergent and radiating; also massive, granular to compact.

$\mathrm{H} .=5-5.5$. G. $=2 \cdot 8-3 ; 2 \cdot 989$, Arendal, Haidinger. Lustre vitreous, rarely subresinous on a surface of fracture; color white; sometimes grayish, pale-green, yellow, red, or amethystine, rarely dirty olive-green or honey-yellow. Streak white. Translucent; rarely opaque white. Fracture uneren, subeonchoidal. Brittle. Plane of optic-axes $i-i$; angle of divergence very obtuse ; bisectrix makes an angle of $4^{\circ}$ with a normal to $i-i$

Var.-1. Ordinary. In crystals, glassy in aspect. Usual forms as in figures. 2 Compact
massive. White opaque, breaking with the surface of porcelain or Wedyewood ware. Frorn the L. Superior region. 3. Botryoidal; Botryolite. Radiated columnar, having a botryoidal surface, and containing more water than the crystals. The original locality of both the crystallized and botryoidal was Arendal, Norway. Haytorite is datolite altered to chalcedony, from the Haytor Iron Mine, England.

Comp-Q. ratio for $\mathrm{H}: \mathrm{Ca}: \mathrm{B}: \mathrm{Si}=1: 2: 3: 4$, like euclase: formula $\mathrm{H}_{2} \mathrm{Ca}_{2} \mathrm{~B}_{2} \mathrm{Si}_{2} \mathrm{O}_{10}=$ Silica $37 \cdot 5$, boron trioxide $21 \cdot 9$, lime $35 \cdot 0$, water $5 \cdot 6=100$. Botryolite contains $10 \cdot 64$ p.c. water.

Pyr., etc.-In the closed tube gives off much water. B.B. fuses at 2 with intrmescence to a clear glass, coloring the flame bright green. Gelatinizes with hydrochloric aci.3.

Diff.-Distinguishing characters: glassy lustre; usually complex crystallization; B.B. fuses easily with a green flame; gelatinizes with acids.

Obs.-Datolite is found in trappean rocks; also in gneiss, dioryte, and serpentine; in metallic veins; sometimes also in beds of iron ore. Found in Scotland; at Arendal ; at Andreasberg; at Baveno near Lago Maggiore ; at the Seisser Alp, Tyrol ; at Toggiana in Modena, in serpentine. In good specimens at Roaring Brook, near New Haven; also at many other localities in the trap rocks of Connecticut ; in N. Jersey, at Bergen Hill ; in the Lake Superior region, and on Isle Royale. San Carlos, Inyo Co., Cal., with garnet and vesuvianite.

## TITANITE.* Sphene.

Monoclinic. $\quad C=60^{\circ} 17^{\prime}=O \wedge i-i ; \quad I \wedge I=113^{\circ} 31^{\prime}, \quad O \wedge 1-i=159^{\circ}$ $39^{\prime} ; c: b: a=0.56586: 1 \cdot 3251: 1$. Cleavage: $I$ 'sometimes nearly perfect; $i-i$ and -1 much less so ; rarely (in greenovite) 2 casy, -2 less so; sometimes hemimorphic. Twins: twimning-plane $i-i$; usually producing thin tables with a reëntering angle along one side; sometimes elongated. as in f. 623. Sometimes massive, compact; rarely lamellar.

H. $=5-5 \cdot 5$. G. $=3 \cdot 4-3 \cdot 56$. Lustre adamantine-resinous. Color brown, gray, jellow, green, and black. Streak white, slightly reddish in greenovite

Transparent-opaque. Brittle. Optic-axial piane $i-i ̀$; bisectrix positive very closely normal to $1-i(x)$; double refraction strong; axial divergence $53^{\circ}-56^{\circ}$ for the red rays, $46^{\circ}-45^{\circ}$ for the blue; DesCl.

Comp., Var.-Q. ratio for $\mathrm{Ca}: \mathrm{Ti}: \mathrm{Si}=1: 2: 2$, or making the Ti basic ( $\mathrm{Ti}=2 \mathrm{R}$ ), $\mathrm{R}: \mathrm{Si}$ $=3: 2$; formula (equivalent to $\mathrm{RSiO}_{5}$ ) $\mathrm{CaTiSiO}_{5}=$ Silica $30 \cdot 61$, titanic oxide $40 \cdot 82$, lime 28.57 $=100$.
Var.-Ordinary. (a) Titanite ; brown to black, the original being thus colored, also opaque or subtranslucent. (b) Sphene (named from $\sigma \phi \hbar \nu$, a wedge) ; of light shades, as yellow, greenish, etc., and often translucent; the original was yellow. Manganesian; Greenorite. Red or rose-colored, owing to the presence of a little manganese. In the crystals there is a great diversity of form, arising from an elongation or not into a prism, and from the occurrence of the elongation in the direction of different diameters of the fundamental form.

Pyr., etc.-B.B. some varieties change color, becoming yellow, and fuse at 3 with intumescence, to a yellow, brown, or black glass. With borax they afford a clear yellowish-green glass. Imperfectly soluble in heated hydrochloric acid; and if the solution be concentrated along with tin, it becomes of a fine violet color. With salt of phosphorus in R.F. gives a violet bead; varieties containing much iron require to be treated with the flux on charcoal with metallic tin. Completely decomposed by sulphuric and fluohydric acids.
Diff.-The resinous lustre is very characteristic ; and its commonly occurring wedge-shaped form. B.B. gives a titanium reaction.
Obs.-Titanite occurs in imbedded crystals, in granite, gneiss, mica schist, syenite, chlorite schist, and granular limestone ; also in beds of iron ore, and volcanic rocks, and often associated with pyroxene, hornblende, chlorite, scapolite, zircon, etc. Found at St. Gothard, and elsewhere in the Alps; in the protogine of Chamouni (pictite, Saus.); at Ala, Piedmont (ligurite) ; at Arendal, in Norway; at Achmatovsk, Urals; at St. Marcel in Piedmont (greenovite, Duf.) ; at Schwarzenstein. Tyrol ; in the Untersulzbachthal in Pinzgau ; near Tavistock; near Tremadoc, in North Wales.
Occurs in Canada, at Grenville, Elmsiey, etc. In Maine, at Sanford. In Mass., at Bolton; at Pelham. In N. York, at Gouverneur; at Diana, in dark-brown crystals (Zederite); in Orange Co.; near Edenville ; near Warwick. In N. Jersey, ¿̇ Franklin. In Penn., Bucks Co., near Attleboro'.
Guarinite. -Same composition as titanite, but orthorhombic (v. Lang and Guiscardi) in crystallization. Color yellow. Mt. Somma.
Kellhauize (Yttrotitanite). -Near sphene in form and composition, but containing alumina and yttria. Arendal, Norway.
Tscheffkinite.-Analogous to keilhauite in composition, containing, besides titanium, also cerium (La,Di). Occurs massive. Ilmen Mts.

## STAUROLITE.

Orthorhombic. $I \wedge I=129^{\circ} 20^{\prime}, O \wedge 1-\bar{\imath}=124^{\circ} 46^{\prime} ; \dot{c}: \bar{b}: \breve{a}=1 \cdot 4406$ $: 2 \cdot 11233: 1$. Cleavage $: i-乞$ distinct, but interrupted; $l$ in traces. Twins


628


629


630

cruciform: twinning-plane $i \frac{-3}{2}$ (f. 628) ; $\frac{3}{2}-\ell$ (f. 629); and $\frac{3}{2} \frac{-3}{2}$ (f. 630). Fig.

Comp.-Composition varies much through impurities, as with other amorphous substances, resulting from alteration. As the silica has been derived from the decomposition of other silicates, it is natural that an excess should appear in many analyses. True chrysocolla corresponds to the Q ratio for $\mathrm{Cu}: \mathrm{Si}: \mathrm{H}, 1: 2: 2=\mathrm{CuSiO}_{3}+2 \mathrm{aq}=$ Silica $34 \cdot 2$, copper oxide $45 \%$, water $20 \cdot 5=100$. But some analyses afford $1: 2: 3$, and $1: 2: 4$. Impure chrysocolla may contain, besides free silica, various other impurities, the color varying from bluish-green to brown and black, the last especially when manganese or copper is present.

Pyr., etc.-In the closed tube blackens and yields water. B.B. decrepitates, colors the flame emerald-green, but is infusible. With the fluxes gives the reactions for copper. With soda and charcoal a globule of metallic copper. Decomposed by acids without gelatinization.

Diff - Color more bluish-green than that of malachite, and it does not effervesce with acids.

Obs.-Accompanics other copper ores, occurring especially in the upper part of veins. Found in most copper mines in Cornwall; at Libethen in Hungary ; at Falkenstein and Schwatz in the Tyrol; in Siberia; the Bannat; Thuringia; Schneeberg, Saxony; Kupferberg, Bavaria; South Australia; Chili, etc. In Somerville and Schuyler's mines, New Jersey; at Morgantown, Pa. ; at Cornwall, Lebanon Co. ; Nova Scotia, at the Basin of Mines; also in Wisconsin and Michigan.

Demidoffite; Cyanochalcite; Resanite; near chrysocolla.
Catapleite.-Analysis (Ramm.), $\mathrm{SiO}_{2} 39 \cdot 78, \mathrm{ZrO}_{2} 40 \cdot 12$, $\mathrm{CaO} 3 \cdot 45, \mathrm{Na}_{2} \mathrm{O} 7 \cdot 59, \mathrm{H}_{2} \mathrm{O} 9-24$ $=100 \cdot 18$. Hexagonal. Color yellowish-brown, Lamöe, near Brevig, Norway.

## B. UNISILICATES.

CALAMINE. Galmei; Kieselzinkerz, Germ.
Orthorhombic ; hemimorphic-hemihedral. $I \wedge I=104^{\circ} 13^{\prime}, 0 \wedge 1-i=$ $148^{\circ} 31^{\prime}$, Daubar; $\dot{c}: \bar{b}: \breve{a}=0.6124: 1 \cdot 2850: 1$. Cleavage: $I$, perfect; $O$, in traces. Also stalactitic, mammillated, botryoidal, and fibrous forms; also massive and granular.
$\mathrm{H} .=4 \cdot 5-5$, the latter when crystallized. G. $=3 \cdot 16-3 \cdot 9$. Lustre vitreous, $O$ subpearly, sometimes adamantine. Color white; sometimes with a delicate bluish or greenish shade; also yellowish to brown. Streak white. Transparenttranslucent. Fracture uneven. Brittle. Pyroelectric.

Comp.-Q. ratio for $\mathrm{R}: \mathrm{Si}: \mathrm{H}=1: 1: \frac{1}{2} ; \mathrm{Zn}_{2} \mathrm{SiO}_{4}+\mathrm{aq}=$ Silica $25 \cdot 0$, zinc oxide $67 \cdot 5$, water $7 \cdot 5=100$.

Pyr., etc.-In the closed tube decrepitates, whitens, and gives off
 water. B.B. almost infusible (F. $\doteq 6$ ) ; moistened with cobalt solution gives a green color when heated. On charcoal with soda gives a coating which is yellow while hot, and white on cooling. Moistened with cobalt solution, and heated in O.F., this coating assumes a bright green color. Gelatinizes with acids even when previously ignited. Decomposed by acetic acid with gelatinization. Soluble in a strong solution of caustic potash.

Diff.-Distinguishing characters: gelatinizing with acids; infusibility; reaction for zinc.
Obs.-Calamine and smithsonite are usually found associated in veins or beds in stratified calcareous rocks accompanying blende, ores of iron, and lead, as at Aix la Chapelle; Bleiberg in Carinthia; Retzbanya; Schemnitz. At Roughten Gill in Cumberland; at Alston Moor; near Matlock in Derbyshire ; at Castleton; Leadhills, Scotland.

In the United States occurs with smithsonite in Jefferson county, Missouri. At Stirling Hill, N. J. In Pennsylvania, at the Perkiomen and Phenixville lead mines; at Bethlehem; at Friedensville. Abundant in Virginia, at Austin's mines.

## PREHNITE.

Orthorhombic. $I \wedge I=99^{\circ} 56^{\prime}, O \wedge 1-\bar{\imath}=146^{\circ} 11 \frac{1}{2}^{\prime} ; \dot{c}: \bar{b}: \breve{u}=0.66963$ $: 1 \cdot 19035: 1$. Cleavage : basal, distinct. Tabular crystals often united by $O$, making broken forms, often barrel-shaped. Usually reniform, globular, and stalactitic with a crystalline surface. Structure imperfectly columnar or lamellar, strongly colerent; also compact granular or impalpable.
$\mathrm{H} .=6-6 \cdot 5 . \mathrm{G} .=2 \cdot 8-2 \cdot 953$. Lustre vitreous; $O$ weak pearly. Color light green, oil-green, passing into white and gray ; often fading on exposure. Subtransparent-translucent; streak uncolored. Fracture uneven. Somewhat brittle.

Comp.-Q. ratio for $\mathrm{R}: \mathrm{R}: \mathrm{Si}: \mathrm{H}=2: 3: 6: 1$, whence, if the water is basic, for basea and silicon, 1:1; formula $\mathrm{H}_{2} \mathrm{Ca}_{2} \mathrm{AlSi}_{3} \mathrm{O}_{12}$ or $\mathrm{Ca}_{2} \mathrm{AlSi}_{3} \mathrm{O}_{11}+\mathrm{aq}=$ Silica $43 \cdot 6$, alumina $24 \cdot 9$, lime $27 \cdot 1$, water $4 \cdot 4=100$.

Pyr., etc.-In the closed tube yields water. B.B. fuses at 2 with intumescence to a blebby enamel-like glass. Decomposed by hydrochloric acid without gelatinizing. C'oupholite, which often contains dust or vegetable matter, blackens and emits a burnt odor.

Diff.-B. B. fuses readily, unlike beryl and chalcedony. Its hardness is greater than that of the zeolites.

Obs.-Occurs in granite, gneiss, syenite, dioryte, and trappean rocks especially the last. At Bourg d'Oisans in Isère; in the Fassathal, Tyrol; Ala in Piedmont; Joachimsthal in Bohemia; near Andreasberg; Arendal, Norway; Adelfors in Sweden; in Dumbartonshire; in Renfrewshire.

In the United States, in Connecticut; Bergen Hill, N. J.; on north shore of Lake Superior ; in large veins in the Erake Superior copper region.

Chlorastrolite and Zonochlorite from Lake Superior are mixtures, as shown by Hawes.
Villarsite.-Probably an altered chrysolite. Formula $\mathrm{R}_{2} \mathrm{SiO}_{4}+\frac{1}{2} \mathrm{aq}$ (or $\frac{1}{8} \mathrm{aq}$ ) $\mathrm{R}=\mathrm{Mg}: \mathrm{Fe}$ $=11: 1$. Traversella.
Cerite, Sweden, and Tritomite, Norway, contain cerium, lanthanum, and didymium. Thorite and Orangite contain thorium. Norway.

Parathorite.-In minute orthorhombic crystals, imbedded in danburite at Danbury, Ct. Chemical nature unknown.

Pyrosmalite.-Analysis by Ludwig, $\mathrm{SiO}_{2} 34 \cdot 66, \mathrm{FeO} 27.05, \mathrm{MnO} 25 \cdot 60, \mathrm{CaO} 0.52, \mathrm{MgO}$ $0.93, \mathrm{H}_{2} \mathrm{O} 8.31, \mathrm{Cl} 4.88=101.85$. In hexagonal tables. Color blackish-green. Nya-Kopparberg, etc., Sweden.

## APOPHYLLITE.*

Tetragonal. $O \wedge 1-i=1.28^{\circ} 38^{\prime} ; \dot{c}=1.2515$. Crystals sometimes nearly

red. Streak uncolored. Transparent; rarely opaque. Brittle. lamellar. cylindrical or barrelshaped. Twins: twin-ning-plane the octahedron 1. Cleavage: $O$ highly perfect; $I$ less so. Also massive and
H. $=4 \cdot 5-5 . \quad$ G. $=2 \cdot 3-$ $2 \cdot 4$. Lustre of $O$ pearly; of the other faces vitreous. Color white, or grayish ; occasionally with a greenish, yellow. ish, or rose-red tint, flesh

Oomp.-Q ratio for $\mathrm{R}: \mathrm{Si}: \mathrm{H}$ usually taken as 1:4:2, part of the oxygen replaced by \&aorine ( $\mathrm{F}_{2}$ ). According to Rammelsberg the ratio is $9: 32: 16$; he writes the formula $4\left(\mathrm{H}_{2} \mathrm{CaSi}_{2} \mathrm{O}_{6}+\mathrm{aq}\right)+\mathrm{KF}$. This requires: Silica $52 \cdot 97$, lime $24 \cdot 72$, potash $5 \cdot 20$, water $15 \cdot 90$, fluorine $2 \cdot 10=100 \cdot 89$. It may be taken as a unisilicate if part of the silica is considered accessory.

Pyr., etc.-In the closed tube exfoliates, whitens, and yields water, which reacts acid. In the open tube, when fused with salt of phosphorus, gives a fluorine reaction. B.B. exfoliates, colors the flame violet (potash), and fuses to a white vesicular enamel. F. $=1 \%$. Decomposed by hydrochloric acid, with separation of slimy silica.

Diff.-Distirguishing characters : its occurrence in square prisms ; its perfect basal cleavage, and pearly lustre on the base.

Obs.-Occurs commonly in amygdaloid and related rocks, with various zeolites; also occasionally in cavities in granite, gneiss, etc. Greenland, Iceland, the Faröe Islands, Andreasberg, the Syhadree, Mountains in Bombay, afford fine specimens. In America, found in Nova Scotia; Bergen Hill, N. J.; the Cliff mine, Lake Superior region.

Chalcomorphite ( $v$. Rath), from limestone inclosures in the lava of Niedermendig. Hexagonal. Essentially an hydrous calcium silicate.
Edingtonite.-Analysis by Heddle, $\mathrm{SiO}_{2} 36.98, \mathrm{AlO}_{3} 22 \cdot 63, \mathrm{BaO} 26.84, \mathrm{CaO} \mathrm{tr}, \mathrm{Na}_{2} \mathrm{O}$ tr., $\mathrm{H}_{2} \mathrm{O} 12 \cdot 46=98 \cdot 91$. Tetragonal. Dumbarton, Scotland.

Gismondite.—Analysis, Marignac, $\mathrm{SiO}_{2} 35 \cdot 38, \mathrm{AlO}_{3} 27 \cdot 23, \mathrm{CaO} 13 \cdot 12, \mathrm{~K}_{2} \mathrm{O} 2 \cdot 85, \mathrm{H}_{2} \mathrm{O} 21 \cdot 10$ $=100 \cdot 18$. Capo di Bove, near Rome; Baumgarten, near Giessen, etc.

Carpiolite.-In radiated tufts in the tin mines of Schlackenwald; Wippra in the Harz. Bases mostly in sesquioxide state ( $\mathrm{Al}, \mathrm{Mn}, \mathrm{Fe}$ ).

## SUBSILICATES.

## ALLOPHANE.

Amorphous. In incrustations, usually thin, with a mammillary surface, and hyalite-like; sometimes stalactitic. Occasionally almost pulverulent.
$\mathrm{H} .=3$. G. $=1 \cdot 85-1 \cdot 89$. Lustre vitreous to subresinous; bright and waxy internally. Color pale sky-blue, sometimes greenish to deep green, brown, yellow, or colorless. Streak uncolored. Translucent. Fracture imperfectly conchoidal and shining, to earthy. Very brittle.

Comp.-Q. ratio for $\mathrm{Al}: \mathrm{Si}: \mathrm{H}$, mostly=3:2:6 (or 5 ); $\mathrm{AlSiO}_{5}+6 \mathrm{aq}$, or $\mathrm{AlSiO}_{5}+5 \mathrm{aq}=$ Silica $23 \cdot 75$, alumina $40 \cdot 62$, water $35 \cdot 63=100$. Plumballophane, from Sardinia, contains a little lead.

The coloring matter of the blue variety is due to traces of chrysocolla, the green to malachite, and that of the yellowish and brown to iron.

Pyr., etc.-Yields much water in the closed tube. B.B. crumbles, but is infusible. Gives a blue color with cobalt solution. Gelatinizes with hydrochloric acid.

Obs.-Allophane is regarded as a result of the decomposition of some aluminous silicate (feldspar, etc.) ; and it often occurs incrusting fissures or cavities in mines, especially those of corper and limonite, and even in beds of coal. Found at Schneeberg in Saxony; at Gersbach ; at the Chessy copper mine, near Lyons; near Woolwich, in Kent, England. In the U. S. it occurs at Richmond, Mass.; at the Friedensville zinc mines, Pa., etc.

Collifrite.-A hydrous silicate of aluminum. Clay-like in structure, white. Hove, England; Schemnitz.

Uranopifane, from Silesia, and Uranotile, from Wölsendorf, Bavaria, are silicates con. taining uranium.

## II. Zeolite Section.

THOMSONITE. Comptonize.
Orthorhombic. $I \wedge I=90^{\circ} 40^{\prime} ; O \wedge 1-\bar{\imath}=144^{\circ} \exists^{\prime} ; c \dot{c}: \bar{b}: \breve{a}=0 \cdot 7225$;
 $1 \cdot 0117$ : 1. Cleavage : $i-\bar{\imath}$ easily obtained; $i-\imath$ less sc ; $O$ in traces. Twins: cruciform, having the vertical axis in common. Also columnar, structure radiated; in radiated spherical concretions; also amorphous and compact.
$H .=5-5 \cdot 5 . \quad$ G. $=2 \cdot 3-2 \cdot 4$. Vitreous, more or less pearly. Snow-white; impure varieties brown. Streak uncolored. Transparent-translucent. Fracture uneven. Brittle. Pyroelectric. Double refraction weak; opticaxial plane parallel to $O$; bisectrix positive, normal to $i-\imath{ }^{\circ}$; divergence $82^{\circ}-82_{2}{ }^{\circ}$ for red rays, from Dumbarton; DesCl.

Var.-Ordinary. (a) In regular crystals, usually more or less rectangular in outline. (b) In slender prisms, often vesicular to radiated. (c) Radiated fibrous. (d) Spherical concresons, consisting of radiated fibres or slender crystals. (e) Massive, granular to impalpable, and white to reddish-brown. Ozarkite is massive thomsonite ; rauite (Norway) is related.

Comp.-Q. ratio for $\mathrm{R}\left(=\mathrm{Ca}, \mathrm{Na}_{2}\right): \mathrm{R}(\mathrm{Al}): \mathrm{Si}: \mathrm{H}=1: 3: 4: 2 \frac{1}{2}, \mathrm{Ca}: \mathrm{Na}_{2}=2: 1$, or $3: 1$; formula $2\left(\mathrm{Ca}, \mathrm{Na}_{2}\right) \mathrm{AlSi}_{2} \mathrm{O}_{4}+5 \mathrm{aq}$. Analysis, Rammelsberg, Dumbarton, $\mathrm{SiO}_{2} 38.09, \mathrm{AlO}_{3}$ $31 \cdot 62, \mathrm{CaO} 12 \cdot 60, \mathrm{Na}_{2} \mathrm{O} 4 \cdot 62, \mathrm{H}_{2} \mathrm{O} 13 \cdot 40=100 \cdot 20$.

Pyr., etc.-At a red heat loses 13.3 p . c. of water, and the mineral becomes fused to $a$ white enamel. B.B. fuses with intumescence at 2 to a white enamel. Gelatinizes with hydrochloric acid.

Obs.-Found in cavities in lava and other igneous rocks; and also in some metanorphic rocks, with elæolite. Occurs near Kilpatrick, Scotland ; in the lavas of Somma (comptonite); in Bohemia; in Sicily ; in Faröe ; the Tyrol, at Theiss; at Monzoni, Fassathal ; at Peter's Point, Nova Scotia ; at Magnet Cove, Arkansas (ozarkite).

NATROLITE. Mesotype. Nadelzeolith, Germ.
Orthorhombic. $\quad I \wedge I=91^{\circ}, O \wedge 1-\bar{\imath}=144^{\circ} \quad 23^{\prime} ; \quad \dot{c}: \bar{b}: \breve{a}=0 \cdot 35825$ : $1 \cdot 0176$ : 1. Crystals usually slender, often acicular ; fre-
 quently interlacing ; divergent, or stellate. Also fibrous, radiating, massive, granular, or compact.
$\mathrm{H} .=5-5 \cdot 5 . \quad \mathrm{G} .=2 \cdot 17-2 \cdot 25 ; 2 \cdot 249$, Bergen Hill, Brush. Lustre vitreous, sometimes inclining to pearly, especially in fibrous varieties. Color white, or colorless; also grayish, yellowish, reddish to red. Streak uncolored. Transparent-translucent. Double refraction weak; op-tic-axial plane $i-\check{\varkappa}$; bisectrix positive, parallel to edge $I / I$; axial divergence $94^{\circ}-96^{\circ}$, red rays, for Auvergne crystals; $95^{\circ} 12^{\prime}$ for brevicite; DesCl.

Comp.-Q. ratio for $\mathrm{R}: \mathrm{R}: \mathrm{Si}: \mathrm{H}=1: 3: 6: 2$; and for $\mathrm{R}: \mathrm{Si}=$ $2: 3\left(\mathrm{R}=\mathrm{Na}_{2}, 3 \mathrm{R}=\mathrm{R}\right)$; formula $\mathrm{Na}_{2}+1 \mathrm{Si}_{3} \mathrm{O}_{10}+2 \mathrm{aq}=$ Silica $47 \cdot 29$, alumina $26 \cdot 96$, soda $16 \cdot 30$, water $9 \cdot 45=100$.

Pyr., etc.-In the closed tube loses water, whitens and becomes opaque. B. B. fuses quietly at 2 to a colorless glass. Fusible in the fame of an ordinary stearine or wax caudle. Ge!a tinizes with acids.

Diff,-Some varieties resemble pectolite, thomsonite, but distinguished B.B.
Obs.-Occurs in cavities in amygdaloidal trap. basalt, and other igneous rocks; and sometimes in seams in granite, gneiss, and syenite. It is found in Bohemia; in Auvergne ; Fassa thal, Tyrol; Kapnik; at Glen Farg in Fifeshire; in Dumbartonshire. In North America, occurs in the trap of Nova Scotia; at Bergen Hill, N. J. ; at Copper Falls, Lake Superior.

## SCOLECITE. Poonahlite.

Monoclinic. $C=89^{\circ} 6^{\prime}, I \wedge I=91^{\circ} 36^{\prime}, O \wedge 1-\grave{\imath}=161^{\circ} 16 \frac{1_{2}^{\prime}}{} ; c: b: a$ $=0.3485: 1 \cdot 0282: 1$. Crystals long or short prisms, or acicular, rarely well terminated, and always compound. Twins: twinning-plane $i-i$. Cleavage: $I$ nearly perfect. Also in nodules or massive; fibrous and radiated.
H. $=5-5 \cdot 5 . \quad$ G. $=2 \cdot 16-2 \cdot 4$. Lustre vitreous, or silky when fibrous. Transparent to subtranslucent. Pyroelectric, the free end of the crystals the antilogue pole. Double refraction weak ; optic-axial plane normal to $i$ divergence $53^{\circ} 41^{\prime}$, for the red rays; bisectrix negative, parallel to $i-i$; plane of the axis of the red rays and their bisectrix inclined about $17^{\circ} 8^{\prime}$ to $i-i$, and $93^{\circ} 3^{\prime}$ to $1-i$.


Comp.-Q. ratio for $\mathrm{R}: \mathrm{R}: \mathrm{Si}: \mathrm{H}=1: 3: 6: 3$; for $\mathrm{R}(3 \mathrm{R}=\mathrm{R}): \mathrm{Si}=2: 3$, as in natrolite; $\mathrm{R}=\mathrm{Ca}, \mathrm{R}=\mathrm{Al}$; formula $\mathrm{CaAlSi} \mathrm{O}_{10}+3 \mathrm{aq}=$ Silica $45 \cdot 85^{2}$, alumina $26 \cdot 13$, lime $14 \cdot 26$, water $13 \cdot 76=100$.

Pyr., etc.-B.B. sometimes curls up like a worm (whence the name from $\sigma \kappa \omega \bar{\lambda} \eta \xi$, a 200 rm , which gives scolecite, and not scolesite or scolezite) ; other varieties intumesce but slightly, and all fuse at $2-2 \cdot 2$ to a white blebby enamel. Gelatinizes with acids like natrolite.

Diff.-Characterized by its pyrognostics.
Obs.-Occurs in the Berufiord, Iceland ; also at Staffa ; in Skye, at Talisker ; near Poonah, Hindostan (Poonahlite); in Greenland ; at Pargas, Finland, etc.

Mesolite.-(Ca, $\left.\mathrm{Na}_{2}\right) \mathrm{AlSi}_{3} \mathrm{O}_{10}+3 \mathrm{aq}\left(5 \mathrm{p} . \mathrm{c} . \mathrm{Na}_{2} \mathrm{O}\right)$. Near scolecite. Iceland; Nova Scotia.
Levynite.-Rhombohedral. Q. ratio for $\mathrm{R}: \mathrm{R}: \mathrm{Si}: \mathrm{H}=1: 3: 6: 4$. Analysis, Damour, Iceland, $\mathrm{SiO}_{2} 45 \cdot 76, \mathrm{AlO}_{3} 23 \cdot 56$, $\mathrm{CaO} 10 \cdot 57, \mathrm{Na}_{2} \mathrm{O} 1 \cdot 36, \mathrm{~K}_{2} \mathrm{O} 1 \cdot 64, \mathrm{H}_{2} \mathrm{O} 17 \cdot 33=100 \cdot 22$. Ireland ; Faröe ; Iceland.

Isometric (?). Usually in trapezohedrons (f. 54, p. 18). Cleavage. cubic, in traces. Also massive granular.
H. $=5-5 \cdot 5$. G. $=2 \cdot 22-2 \cdot 29 ; 2 \cdot 278$, Thomson. Lustre vitreous. Colorless; white; occasionally grayish, greenish, yellowish, or reddish-white. Streak white. Transparent-uearly opaque. Fracture subconchoidal, uneven. Brittle.

Comp.-Q. ratio for $\mathrm{R}: \mathrm{R}: \mathrm{Si}: \mathrm{H}=1: 3: 8: 2, \mathrm{R}=\mathrm{Na}_{2}, \mathrm{R}=\mathrm{Al}=3 \mathrm{R} ; \mathrm{R}: \mathrm{Si}=1: 2$. For mula $\mathrm{Na}_{2} \mathrm{AlSi}_{4} \mathrm{O}_{12}+2 \mathrm{aq}=$ Silica $54 \cdot 47$, alumina $23 \cdot 29$, soda $14 \cdot 07$, water $8 \cdot 17=100$.

Pyr., etc.-Yields water in the closed tube. B.B. fuses at 2.5 to a colorless glass. Gelatinizes with hydrochloric acid.

Diff.-Distinguishing characters : crystalline form ; absence of cleavage; fusion B.B. without intumescence to a clear glass (unlike chabazite).

Obs.-Some localities are : the Tyrol ; the Kilpacrick Hills in Scotland; the Faröe Islands ; Iceland: Aussig, Bohemia; Nova Scotia; Bergen Hill, New Jersey; the Lake Superior region.

Schrauf has found that the analcite of rrieueck, Bohemia, is properly tetragonal; the simplest crystals showing evidence of repeated twinning.

Faudastite.-An octahedral zeolite from the Kaiserstuhlgebirge. Analysis, Damour, SiO, $46 \cdot 12, \mathrm{AlO}_{3} 16 \cdot 81, \mathrm{CaO} 4 \cdot 79, \mathrm{Na}_{2} \mathrm{O} 5 \cdot 09, \mathrm{H}_{2} \mathrm{O} 27 \cdot 02=99 \cdot 83$.
Eudnophite. Near analcite. In syenite near Brevig, Norway.
Pilinite. - In slender needles (orthorhombic); white ; lustre silky. Analysis $\mathrm{SiO}_{2} 55 \cdot 70$, $\mathrm{AlO}_{3}\left(\mathrm{FeO}_{3}\right) 18 \cdot 64, \mathrm{CaO} 19.51, \mathrm{Li}_{2} \mathrm{O}(1 \cdot 18), \mathrm{H}_{2} \mathrm{O} 4 \cdot 97=100$. In granite of Striegau, Silesia (Lasaulx).

## CHABAZITE.*

Rhombohedral. $R \wedge R=94^{\circ} 46^{\prime}, O \wedge R=129^{\circ} 15^{\prime} ; \dot{c}=1 \cdot 06$. Twins: twinning-plane $O$, very comınon, and usually in compound twins, as in f. 644 ; also $R$, rare. Cleavage rhombohedrall, rather distinct.

$\mathrm{H} .=4-5$. G. $=2 \cdot 08-2 \cdot 19$. Lustre vitreous. Color white, flesh-red; streak uncolored. Transparent-translucent. Fracture uneven. Brittle. Double refraction weak; in polarized light, images rather confused; axis in some crystals (Bohemia) negative, in others (from Andreasberg) positive ; DesCl.

Var.-1. Ordinary. The most common form is the fundamental rhombohedron, in which the angle is so near $90^{\circ}$ that the crystals were at first mistaken for cubes. Acadialite, from Nova Scotia (Acadia of the French of last century), is only a reddish chabazite; sometimes nearly colorless. In some specimens the coloring matter is arranged in a tesselated manner, or in layers, with the angles almost colorless. 2. Phacolite is a colorless variety occurring in twins of mostly a hexagonal form, and often much modified so as to be lenticular in shape (whence the name, from фaкós, a bean); the original was from Leipa in Bohemia; $R \wedge \Omega$ $=94^{\circ} 24^{\prime}$, fr. Oberstein, Breith.

Comp.-Making part of the water basic (at $300^{\circ}$ C. loses $17-19$ p. c.) Rammelsberg writes the formula $(\mathrm{H}, \mathrm{K})_{2} \mathrm{CaAllSi}_{5} \mathrm{O}_{1 s}+6 \mathrm{aq}$, where the $Q$. ratio for $\mathrm{R}: \mathrm{R}: \mathrm{Si}=2: 3: 10, R=\mathrm{H}_{2}, \mathrm{Na}_{2}$, Ca ; or $(3 \mathrm{R}=\mathrm{R}), \mathrm{R}: \mathrm{Si}=1: 2$. The formula corresponds to Silica $50 \cdot 50$, alumina $17 \cdot 26$, lime $9 \cdot 43$, potash $1 \cdot 98$, water $20 \cdot 83=100$.

Pyr., etc.-B.B. intumesces and fuses to a blebby glass, nearly opaque. Decomposed by hydrochloric acid, with separation of slimy silica.

Diff.-Its rhombohedral form, resembling a cube, is characteristic ; is harder, and does not effervesce with acids like calcite; is unlike fluorite in cleavage ; fuses B. B. with intumescence to a blebby glass, unlike analcite.
Obs.-Chabazite occurs mostly in trap, basalt, or amygdaloid, and occasionally in gneiss, syenite, mica schist, hornblendic schist. At the Faröe Islands, Greenland, and Iceland ; at Aussig in Bohemia; Striegau, Silesia. In Nova Scotia, wine-yellow or flesh-red (the last the acadiclite), etc.; at Bergen Hill, N. J.; at Jones's Falls, near Baltimore (haydenite).

Seebachite (Bauer) from Richmond, Victoria, is, according to v. Rath, identical with phacolite; and he suggests the same may be true of Herschelite, from Asi Castello, Sicily.

## GMELINITE.

Rhombohedral. $R \wedge R=112^{\circ} 26^{\prime}, \quad O \wedge R=O \wedge-1=140^{\circ} 3^{\prime} ; d=$ 0.7254 . Crystals usually hexagonal in aspect ; sometimes habit rhombohedral; $i$ often horizontally striated. Cleavage: $i$ perfect. Observed only in crystals, and never as twins.
$H .=4 \cdot \breve{0} . G .=2 \cdot 04-2 \cdot 17$. Lustre vitreous. Colorless, yellowish-white, greenishwhite, reddish-white fleshred. Transparent to trans-

C. Blomidon, etc.

C. Blomidon. lucent. Brittle.

Comp.-Q. ratio for $\mathrm{R}: \mathrm{R}: \mathrm{Si}: \mathrm{H}=1: 3: 8: 6, \mathrm{R}=\mathrm{Ca}\left(\mathrm{Na}_{2}, \mathrm{~K}_{3}\right), \mathrm{R}=\mathrm{Al}$. Formula ( $\mathrm{Ca}, \mathrm{Na} \mathrm{a}_{2}$ ) AlSi ${ }_{4} \mathrm{O}_{12}+6$ aq. Analysis by Howe, Bergen $\mathrm{Hill}, \mathrm{SiO}_{2} 48 \cdot 67, \mathrm{HlO}_{3} 18 \cdot 72, \mathrm{FeO}_{3} 0 \cdot 10, \mathrm{CaO}$ $2 \cdot 60, \mathrm{Na}_{2} \mathrm{O} 9 \cdot 14, \mathrm{H}_{2} \mathrm{O} 21 \cdot 3 \overline{5}=100 \cdot 58$ (Am. J. Sci., III., xii., 270,1876 ).

Pyr., etc.-In the closed tube crumbles, gives off much water. B.B. fuses easily to a white enamel. Decomposed by hydrochloric acid with gelatinization.

Diff.-Closely resembles some chabazite, but differs decidedly in angle.
Obs.-Occurs at Andreasberg; in Translyvania ; in Antrim, Ireland; near Larne; at Talisker in Skye; at Cape Blomidon and other localities in Nova Scotia (ledererite); in fine crystals of varied habit at the Bergen Hill tunnel of 1876.

PHILLIPSITE.*
Orthorhombic. $I \wedge I=91^{\circ} 12^{\prime} ; 1 \wedge 1=121^{\circ} 20^{\prime}, 120^{\circ} 44^{\prime}$, and $88^{\circ} 40^{\prime}$ Marignac. Faces 1 and $i-\bar{i}$ striated parallel to the edge between them. Simple crystals unknown. Commonly in cruciform crystals, consisting of two crossing crystals, each a twinned prism (f. 647). Crystals either isolated, or grouped in tufts or spheres that are radiated within and bristled with angles at surface.
II. $=4-4 \cdot 5$. G. $=2 \cdot 201$. Lustre vitreons. Color white, sometimes reddish. Streak uncolored. Translucent-opaque.

Comp.-Q. ratio for $R: R: S i: H=1: 3: 8: 4, R=C a$ and $\mathrm{K}_{2}\left(\mathrm{Na}_{2}\right) ; \mathrm{Ca}: \mathrm{K}_{2}=3: 1,2: 3$, etc. Formula $\mathrm{R} 41 \mathrm{Si}_{4} \mathrm{O}_{12}$ +4aq. Analysis by Ettling, Nidda. Hessen, $\mathrm{SiO}_{2} 48 \cdot 13$, $\mathrm{AlO}_{3} \cdot 21 \cdot 41, \mathrm{CaO} 8 \cdot 21, \mathrm{~K}_{2} \mathrm{O} 5 \cdot 20, \mathrm{Na}_{2} \mathrm{O} 0 \cdot 70, \mathrm{H}_{2} \mathrm{O} 16 \cdot 78=$ $100 \cdot 48$.

Pyr., etc.-B.B. crumbles and fuses at 3 to a white enamel. Gelatinizes with hydrochloric acid.

Diff.-Resembles harmotome, but distinguished B.B.
Obs.-At the Giant's Causeway, Ireland; at Capo di Bove. near Rome ; in Sicily ; Annerode, near Giessen; in Silesia; Bohemia ; on the west coast of Iceland.

Streng (Jahrb. Min., 1876, 585) shows that the forms are exactly analogous to those of harmotome, and suggests that it may be also monoclinic.

C. di Bove.

## HARMOTOME.

Monoclinic (DesCloizeaux). Cleavage: $I, O$, easy. Simple erystals unknown. Occurring in penetra. tion-twins. Unknown massive.
$\mathrm{H} .=4 \cdot 5 . \quad$ G. $=2 \cdot 44-2 \cdot 45$. Lustre vitreous. Color white; passing into gray, yellow, red, or brown. Streak white. Sub-transparent-translucent. Fracture uneven, imperfectly conchoidal. Brittle.

Comp.-Q. ratio for $\mathrm{R}: \mathrm{R}: \mathrm{Si}: \mathrm{H}$ $=1: 3: 10: 5$; here $\mathrm{R}=\mathrm{Ba}$ mostly, also $\mathrm{K}_{2} ; \mathrm{R}=\mathrm{Al}$. Formula $\mathrm{RAlSi} \mathrm{S}_{5} \mathrm{O}_{14}$ +5 aq . If one-fifth of the water is chemically combined (Rammelsberg), then the formula corresponds to $\mathrm{H}_{2} \mathrm{RAlSi} \mathrm{O}_{15}+4 \mathrm{aq}$. Both formulas give Silica $45 \cdot 91$, alumina $15 \cdot 70$, baryta $20 \cdot 06$, potash $3 \cdot 34$, water $14 \cdot 99=100$.

Pyr., etc.-B.B. whitens, then crumbles and fuses at $3 \cdot 5$ without intumescence to a white translucent glass. Some varieties phosphoresce when heated. Decomposed by hydrochloric acid without gelatinizing.

Diff.-Characterized by its crystallization in twins; the presence of barium separates it from other species.

Obs.-Harmotome occurs in amygdaloid, phonolyte, trachyte; also on gneiss, and in some metalliferous veins. At Strontian in Scotland; at Andreasberg; at Rudelstadt in Silesia, Schiffenberg, near Giessen, etc.; Oberstein; in the gneiss of upper New York City.

DesCloizeaux, who has shown the monoclinic character of the species by optical means, has adopted a different position for the crystals ( $1=I$, etc.).

## STILBITE.* Desmine.

Orthorhombic. $I \wedge I=94^{\circ} 16^{\prime}, 1 \wedge 1$, front, $=119^{\circ} 16^{\prime}$, side, $114^{\circ} 0^{\prime}$. Cleavage : $i-\imath$ perfect, $i-\bar{\imath}$ less so. Forms as in f. 650 ;
 more common with the prism flattened parallel to $i-\frac{\pi}{2}$ or the cleavage-face, and pointed at the extremities. Twins: cruciform, twinning-plane. $1 \cdot \bar{\imath}$, rare. Common in sheaf-like aggregations; divergent or radiated ; some times globular and thin lamellar-columnar.
H. $=3 \cdot 5-4 . \quad$ G. $=2 \cdot 094-2 \cdot 205$. Lustre of $i-乞$ pearly ; of other faces vitreons. Color white; occasionally yellow, brown, or red, to brick-red. Streak uncolored. Transparent-translucent. Fracture uneven. Brittle.

Var.-1. Ordinary. Either (a) in crystals, flattened and pearly parallel to the plane of cleavage, or sheaf-like, or divergent groups; or (b) in radiated stars or hemispheres, with the radiating individuals showing a pearly cleavage surface. Sphcerostilbite, Beud, is in spheres, radiated within with a pearly fracture, rather soft externally.
Comp.-Q. ratio for $\mathrm{R}: \mathrm{R}: \mathrm{Si}: \mathrm{H}=1: 3: 12: 6 ; \mathrm{R}=\mathrm{Ca}(\mathrm{Na} 2), \mathrm{R}=\mathrm{Al}$. Formula R AlSi $\mathrm{CO}_{1}$ +6 aq . If two parts of water are basic (Ramm.) the ratio becomes $\left(\mathbf{R}=\mathrm{Ca}, \mathrm{H}_{2}, \mathrm{Na}_{2}\right) 3: 3: 12$ $: 4$, or $\mathrm{R}: \mathrm{Si}=1: 2$, and the formula is $\mathrm{H}_{4} \mathrm{R} A 1 \mathrm{Si}_{6} \mathrm{O}_{18}+4 \mathrm{aq}$. Analysis, Petersen, Seisser Alp, $\mathrm{SiO}_{2} 55 \cdot 61, \mathrm{AlO}_{3} 15 \cdot 62, \mathrm{CaO} 7 \cdot 33, \mathrm{Na}_{2} \mathrm{O} 2 \cdot 01, \mathrm{~K}_{2} \mathrm{O} 0 \cdot 47, \mathrm{H}_{2} \mathrm{O} 18 \cdot 19=99 \cdot 23$.
Pyr., eto.-B.B. exfoliates, swells up, curves into fan-like or vermicular forms, and fuses
to a white enamel. F. =2-2 5. Decomposed by hydrochloric acid, without gelatinizing. The sphacrostilbite gelatinizes, but Heddle says this is owing to a mixture of mesolite with the stilbite.

Diff.--Prominent characters: occurrence in sheaf-like forms, and in the rectangular tabular crystals; lustre on cleavage-face pearly; does not gelatinize with acids.

Obs.-Stilbite occurs mostly in cavities in amygdaloid. It is also found in some metalliferous veins, and in granite and gneiss. The Farje Islands, Iceland, and the Isle of Skye ; in Dumbartonshire, Scotland; at Andreasberg; Arendal in Norway; in the Syhadree Mts., Bombay ; near Fahlun, in Sweden. In North America, at Bergen Hill, New Jersey ; at the Michipicoten Islands, Lake Superior ; Nova Scotia, etc.

The name stilbite is from orin $\beta \eta$, lustre; and desmine from réбun, a bundle. The species stilbite, as adopted by Haüy, included Strahlzeolith Wern. (radiated zeolite, or the above), and Blätterzeolith Wern. (foliated zeolite, or the species heulandite beyond). The former was the typical part of the species, and is the first mentioned in the description; and the lattel he added to the species, as he observes, with much hesitation. In 1817, Breithaupt separated the two zeolites, and called the former desmine and the latter euzeolite, thus throwing aside entirely, contrary to rule and propriety, Haüy's name stilbite, which should have been accepted by him in place of desmine, it being the typical part of his species In 1822, Brooke (apparently unaware of what Breithaupt had done) used stilbite for the first, and named the other heulandite. In this he has been followed by the French and English mineralogists, while the Germans have unfortunately followed Breithaupt.

Epistilbite (Reixsite).-Composition like heulandite, but form orthorhombic. Iceland; Faröe; Poonah, India, etc. ; Bergen Hill, N. J.

Foresite.-Resembles stilbite in form. Q. ratio for R : $\mathrm{R}: \mathrm{Si}: \mathrm{H}-1: 6: 12: 6$. Formula $\mathrm{R} \mathrm{Hl}_{2} \mathrm{Si}_{6} \mathrm{O}_{19}+6$ aq. ( $\mathrm{R}=\mathrm{Na}_{2}: \mathrm{Ca}=1: 3$ ). Occurs in crystalline crusts on tourmaline, in cavities in granite. Island of Elba.
heulandite. Stilbit, Germ.

Monoclinic. $C=88^{\circ} 35^{\prime}, I \wedge I=136^{\circ} 4^{\prime}, O \wedge 1-\grave{\imath}=156^{\circ} 45^{\prime} ; c: \imath: \grave{a}=$ $1 \cdot 065: 24785: 1$. Cleavage : clinodiagonal ( $i-i$ ) eminent. Also in globular forms; also granular.

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H. $=3 \cdot 5-4$. G. $=2 \cdot 2$. Lustre of $i-2$ strong pearly ; of other faces vitreous. Color varions shades of white, passing into red, gray, and brown. Streak white. Transparent-subtranslucent. Fracture subconchoidal, uneven. Brittle. Double refraction weak; optic-axial plane normal to $i-i$; bisectrix positive, parallel to the horizontal diagonal of the base; DesCl.

Comp.-Q. ratio for $\mathrm{R}: \mathrm{R}: \mathrm{Si}: \mathrm{H}=1: 3: 12: 5 ; \mathrm{R}=\mathrm{Ca}\left(\mathrm{Na}_{2}\right)$. Formula CatlSi $\mathrm{O}_{16}+5 \mathrm{aq}$, or if $2 \mathrm{H}_{2} \mathrm{O}$ be basic (Ramm.) then the ratio becomes 1:1:4 ( $\mathrm{R}=\mathrm{Ca}$ and $\mathrm{H}_{2}$ ), and the formula $\mathrm{H}_{4} \mathrm{CaAlSi}_{6}$
 $\mathbf{O}_{18}+3$ aq. Both require Silica $59 \cdot 06$, alumina $16 \cdot 83$, lime $7 \cdot 88$, soda $1 \cdot 46$, water $14 \cdot 77=100$.

Pyr.-B.B. same as with stilbite.
Diff.-Distinguished by its crystalline form. Pearly lustre of $i-i$ a prominent character.
Obs.-Heulandite occurs principally in amygdaloidal rocks. Also in gneiss, and occasionally in metalliferous veins. Occurs in Iceland; the Faröe Islands; the Vendayah Mountains, Hindostan. Also in the Kilpatrick Hills. vear Glasgow; in the Fassa Valley, Tyrol ; Andreasberg ; Nova Scotia, etc. ; at Bergen Hill, New Jersey ; on north shore of Lake Superior; at Jones's l'alls, near Baltimore (Levy's beaumontite).

For the relation of the synonymes see stilbit, above.
Brewsterite.-Q. ratio same as for heulandite, but R is here Ba or Sr ( Ca ). Formula requires $\mathrm{SiO}_{2} 53 \cdot 5, \mathrm{AlO}_{3} 15 \cdot 3, \mathrm{BaO} 7 \cdot 6$, $\mathrm{SrO} 10 \cdot 2, \mathrm{H}_{2} \mathrm{O} 13 \cdot 4=100$. Monoclinic. Strontian in Argyleshire, etc.

## III. Margarophylutte Segtion.

## Bisilicates.

The Margarophyllites are often foliated like the micas, and the name alludes to the pearly folia. Massive varieties are, however, the most common with a large part of the species, and they often have the compactness of clay or wax. Talc, pyrophyllite, serpentine, are examples of species presenting both extremes of structure; while pinite occurs, as thus far known, only in the compact condition. The true Margarophyllites are below 5 in hardness; greasy to the feel, at least when finely powdered.

## talC.

Orthorhombic. $I \wedge I=120^{\circ}$. Occurs rarely in hexagonal prisms and prates. Cleavage : basal, eminent. Foliated massive, sometimes in globular and stellated groups; also granular massive, coarse or fine; also compact or cryptocrystalline.
$\mathrm{H} .=1-1 \cdot 5$. G. $=2 \cdot 565-2 \cdot 8$. Lustre pearly. Color apple-green to white, or silvery-white; also greenish-gray and dark green; sometimes bright green perpendicular to cleavage surface, and brown and less translucent at right angles to this direction ; brownish to blackish-green and reddish when impure. Streak usually white; of dark green varieties, lighter than the color. Subtransparent-subtranslucent. Sectile. Thin laninæ flexible, but not elastic. Feel greasy. Optic-axial plane $i-\bar{\imath}$; bisectrix negative, normal to the base; DesCl.

Var.-Foliated, Talc. Consists of folia, usually easily separated, having a greasy feel, and presenting ordinarily light green, greenish-white, and white colors. G. $=2 \cdot 55-2.78$. ( $a$ ) Massive, Steatite or Soapstone (Speckstein, Germ.). Coarse granular, gray, grayish-green, and brownish-gray in colors. $H .=1-2 \%$. (b) Fine granular or cryptocrystalline, and soft enough to be used as chalk, as the Froench challk (Craie de Briançon), which is milk-white, with a pearly lustre.

Comp.-Q. ratio for $\mathrm{Mg}: \operatorname{Si}=2: 5$, or $3: 4$, with a varying amount of water in both talc and steatite, from a fraction of a per cent. to 7 p . c. If the water is basic, the ratio becomes for $\mathrm{R}: \mathrm{Si}=1: 2,\left(\mathrm{R}=\mathrm{Mg}(\mathrm{Fe})\right.$ and $\left.\mathrm{H}_{2}\right)$, and the formula is $\mathrm{H}_{2} \mathrm{Mg}_{3} \mathrm{Si}_{4} \mathrm{O}_{12}$ (Ramm.) = Silica $63 \cdot 49$, magnesia $31 \cdot 75$, water $4 \cdot \% 6=100$; the aralyses show generally 1 or 2 p. c. of FeO .
Pyr., etc.-In the closed tube B.B., when intensely ignited, most varieties yield water. In the platinum forceps whitens, exfoliates, and fuses with difficulty on the thin edges to a white enamel. Moistened with cobalt solution, assumes on ignition a pale red color. Not decomposed by acids.

Diff--Recognized by its extreme softness, unctuous feel, and usually foliated structure. Inelastic though flexible. Yields water only on intense ignition.

Obs.-Talc or steatite is a very common mineral, and in the latter form constitutes extensive beds in some regions. It is often associated with serpentine and dolomite, and frequently contains crystals of dolomite, breunerite, asbestus, actinolite, tourmaline, magnetite. Steatite is the material of many pseudomorphs, among which the most common are those after pyroxene, hornblende, mica, scapolite, and spinel. The magnesian minerals are those which commonly affurd steatite by alteration; while those, like scapolite and nephelite, which contain soda and no magnesia, most frequent|y' change to pinite-like pseudomorphs. Rensselaerite and py rallulite are pseudomorphous varieties.

Apple-green talc occurs near Salzburg; in the Valais; also in Cornwall, near Lizard Point, with serpentine; in Scotland, with serpentine, at Portsoy and elsewhere; etc. In N. America, some localities are: Vermont, at Bridgewater; Grafton, etc. In New Hampshire, at Pelham, etc. In R. Island, at Smithfield. In N. York, near Amity. In Penn., at Texas; at Chestnut. Hill, on the Schuylkill. In Maryland, at Cooptown.

PYROPHYLLITE. Agalmatolite or Pagodite pt.
Orthorhombic. Not observed in distinct crystals. Cleavage: basal eminent. Foliated, radiated lamellar; also granular, to compact or cryptocrystalline; the latter sometimes slaty.
H. $=1-2$. G. $=2 \cdot 75-2 \cdot 92$. Lustre of folia pearly, like that of talc ; of massive kinds dull or glistening. Color white, apple-green, grayish and brownish-green, yellowish to ochre-yellow, grayish-white. Subtransparent to opaque. Laminæ flexible, not elastic. Feel greasy. Optic-axial angle large (about $105^{\circ}$ ); bisectrix negative, normal to the cleavage-plane.

Var.-(1) Foliated, and often radiated, closely resembling talc in color, feel, lustre, and structure. (2) Compact, massive, white, grayish, and greenish, somewhat resembling compact steatite, or French chalk. This compact variety, as Brush has shown, includes part of what has gone under the name of agalmatolite, from China ; it is used for slate-pencils, and is sometimes called pencil-stone.

Comp.-Q. ratio for $\mathrm{Al}: \mathrm{Si}=1: 2$, also in other cases $3: 8$, Formula for the first case $=$ $\mathrm{AlSi}_{3} \mathrm{O}_{9}+\mathrm{aq}$ (Ramm.). Analysis, Chesterfield, S. C., by Genth, $\mathrm{SiO}_{2} 64 \cdot 82, \mathrm{AlO}_{3} 28 \cdot 48, \mathrm{FeO}_{3}$ $0 \cdot 96, \mathrm{MgO} 0 \cdot 33, \mathrm{CaO} 0.55, \mathrm{H}_{2} \mathrm{O} 5 \cdot 25=100 \cdot 39$.
Pyr., etc.-Yields water. B.B. whitens, and fuses with difficulty on the edges. The radiated varieties exfoliate in fan-like forms, swelling up to many times the original volume of the assay. Heated with cobalt solution gives a deep blue color (alumina). Partially decom. posed by sulphuric acid, and completely on fusion with alkaline carbonates.

Obs.-Compact pyrophyllite is the material or base of some schistose rocks. The foliated variety is often the gangue of cyanite. Occurs in the Urals; at Westana, Sweden; near Ottrez in Luxembourg ; in Chesterfield Dist., S. C. ; in Lincoln Co., Ga.; in Arkansas. The compact pyrophyllite of Deep River, N. C., is extensively used for making slate pencils.

Piflite (cymatolite), near pyrophyllite.

Compact, with a smooth feel, and fine earthy texture, or clay-like.
$H$. $=2-2 \cdot 5$. Impressible by the nail. In dry masses floats on water. Color grayish-white, white, or with a faint yellowish or reddish tinge. Opaque.

Comp.-Q. ratio for $\mathrm{R}: \mathrm{Si}: \mathrm{H}=1: 3: 1$, corresponding to $\mathrm{Mg}_{2} \mathrm{Si}_{3} \mathrm{O}_{8}+2 \mathrm{aq}$; or, if half the water is basic, $1: 2: \frac{1}{8}=\mathrm{H}_{2} \mathrm{Mg}_{2} \mathrm{Si}_{3} \mathrm{O}_{9}+\mathrm{aq}=$ Silica $60 \cdot 8$, magnesia $27 \cdot 1$, water $12 \cdot 1=100$. The amount of water present is somewhat uncertain.

Pyr., etc.-In the closed tube yields first hygroscopic moisture, and at a higher temperature gives much water and a burnt smell. B. B. some varieties blacken, then burn white, and fuse with difficulty on the thin edges. With cobalt solution a pink color on ignition. Decomposed by hydrochloric acid with gelatinization.

Obs.-Occurs in Asia Minor, in masses in stratified earthy or alluvial deposits at the plains of Eskihi-sher ; also found in Greece; at Hrubschitz in Moravia ; in Morocco ; at Vallecas in Spain, in extensive beds.

The word meerschaum is German for sea-froth, and alludes to its lightness and color. Sepiolite, Glocker, is from $\sigma \eta \pi \iota a$, cuttle-fish, the bone of which is light and porous, and also a production of the sea.

APHRODITE. $-4 \mathrm{MgSiO}_{3}+3 \mathrm{aq}$. Resembles sepiolite. Longban, Sweden.
Smectite.-Fuller's earth pt. A greenish clay from Styria.
Montmorillonite.-A rose-red clay containing more alumina than smectite, from Montmorillon, France.

Celadonite.-A variety of "green earth" from Mt. Baldo, near Verona.
Glauconice.-Green earth pt. A hydrous silicate of iron and potassium, but alwaya impure. Constitutes the green sand of the chalk and other formations (e.g., in New Jersey).

Stilpaomelank, -In foliated plates, or as a velvety coating. Essentially a hydrous iron
(Fe) silicate. Color black to yellowish-bronze. Silesia; Weilburg; Nassau; Sterling irun mine; Antwerp, N. Y. (chalcodite).

Chloropal.-Compact, earthy. Color greenish-yellow. A hydrated iron silicate. Formula $\mathrm{FeSi}_{3} \mathrm{O}_{9}+5 \mathrm{aq}$. Andreasberg ; Steinberg near Göttingen; Nontron (nontronite), France, etc. Aerinite.-Perhaps related to chloropal (Lasaulx). Color blue. Spain.

## Unisilicates.

## Serpentine Group.

## SERPENTINE.*

Orthorhombic (\%). In distinct crystals, but only as psendomorphs. Sometimes foliated, folia rarely separable; also delicately fibrous, the fibres often easily separable, and either flexible or brittle. Usually massive, fine granular to impalpable or cryptocrystalline; also slaty.
$\mathrm{H}=2 \cdot 5-4$, rarely $5 \cdot 5 . \mathrm{G} .=2 \cdot 5-2 \cdot 65$; some fibrous varieties $2 \cdot 2-2 \cdot 3$; retinalite, $2 \cdot 36-2 \cdot 55$. Lustre subresinous to greasy, pearly, earthy ; resinlike, or wax-like; usually feeble. Color leek-green, blackish-green, oil and siskin-green, brownish-red, brownish-yellow; none bright; sometimes nearly white. On exposure, often becoming yellowish-gray. Streak white. slightly shining. Translucent-opaque. Feel smooth, sometimes greasy. Fracture conchoidal or splintery.

Var.-Many unsustained species have been made out of serpentine, differing in structure (massive, slaty, foliated, fibrous), or, as supposed, in chemical composition.
Massive. (1) Ordinary massive. (a) Precious or Noble Serpentine (Edler Serpentin, Germ.) is of a rich oil-green color, of pale or dark shades, and translucent even when in thick pieces; and (b) Common Serpentine, when of dark shades of color, and subtranslucent. The former has a hardness of 2.5-3; the latter often of 4 or beyond, owing to impurities. Bowenito (Smithfield, R. I.), is a jade-like variety with the hardness 5.5 .

Foliated. Marmolite is thin foliated; the laminæ brittle but easily separable, yet graduating into a variety in which they are not separable. G. $=2.41$; lustre pearly; colors green-ish-white, bluish-white, or pale asparagus-green. From Hoboken, N. J.

FIbrous. C'hrysotile is delicately fibrous, the fibres usually flexible and easily separating ; lustre silky, or silky metallic; color greenish-white, green, olive-green, yellow, and brownish; G. $=2.218$. Often constitutes seams in serpentine. It includes most of the silky amianthus of serpentine rocks. The original chrysotile was from Reichenstein.

Any serpentine rock cut into slabs and polished is called serpentine marble.
Comp.-Q. ratio for $\mathrm{Mg}: \mathrm{Si}: \mathrm{H}=3: 4: 2$, corresponding to $\mathrm{Mg}_{3} \mathrm{Si}_{2} \mathrm{O}_{7}+2 \mathrm{aq}=$ Silica $43 \cdot 48$, magnesia $43 \cdot 48$, water 13.04 . But as chrysolite is especially liable to the change to scrpentine, and chrysolite is a unisilicate, and the change consists in a loss of some Mg . and the addition of water, it is probable that part of the water takes the place of the lost Mg, so that the mineral is essentially a hydrated chrysolite of the formula $\mathrm{H}_{2} \mathrm{Mg}_{3} \mathrm{Si}_{2} \mathrm{O}_{8}+$ aq. The relation in ratio to kaolinite and pinite corresponds with this view of the formula.
Pyr., etr.-In the closed tube yields water. B B. fuses on the edges with difficulty. F.= 6. Gives usually an iron reaction. Decomposed by hydrochloric and sulphuric acids. Chrysotile leaves the silica in fine fibres.
Diff.-Distinguishing characters: compact structure; softness, being easily cut with a knife; low specific gravity; and resinous lustre.

Obs.-Serpentine often constitutes mountain masses. It frequently occurs mixed with more or less of dolomite, magnesite, or calcite, making a rock of clouded green, sometimes veined with white or pale green, called verd antique, or ophiolite. It results from the alteration of other rocks, frequently chrysolite rocks. Crystals of serpentine (psendomorphous) ncour in the Fasse valley, Tyrol; near Miask; Katharinenberg, and elsew'here; in Norway,
at finarum, etc. Precious serpentines come from Sweden; the Isle of Man; Corsica; Siberia: Saxony, etc. In N. America, in Vermont, at New Fane; Roxbury, etc. In Mass., at Newburyport and elsewhere. In Conn., near New Haven and Milford, at the verd-antique quarries. In N. York, at Brewster, Putnam Co. ; at Antwerp, Jefferson Co. ; in Gouverneur, St. Lawrence Co.; in Orange Co.; Richmond Co. In N. Jersey, at Hoboken. In Penn., at Texas, Lancaster Co.; also in Chester Co. ; in Delaware Co. In Maryland, at Bare Hills; at Cooptown, Harford Co.

The following are varieties of serpentine : retinalite, Grenville, C. W. ; vorhauserite, Tyrol ; porcellophite ; bovoenite, Smithfield, R. I. ; antigorite, Piedmont; wilhiamsite, Texas, Pa. ; marmolite, Hoboken; picrolite; metaxite; refdanskite (containing Ni) ; aquacreptite.

Bastite or Schililer Spar. - An impure serpentine, a result of the alteration of a foliated pyroxene. Baste; Todtmoos in the Schwarzwald. Antillite is similar.

Deweylite (Gymnite). $-\mathrm{H}_{4} \mathrm{Mg}_{4} \mathrm{Si}_{3} \mathrm{O}_{12}+4 \mathrm{aq}$. Occurs with serpentine at Middlefield and Texas, Penn. Hydrophite (Jenkinsite), near deweylite, but Mg replaced in part by Fe.

Cerolite. $-\mathrm{H}_{2} \mathrm{Mg}_{2} \mathrm{Si}_{2} \mathrm{O}_{7}+$ aq. Silesia. Limbachite from Limbach, and Zöblitzite from Zöblitz, are varieties of cerolite.

GENTHITE. Nickel-Gymnite.
Amorphous, with a delicately hemispherical or stalactitic surface, in crusting.
$\mathrm{H}=3-4$; sometimes (as at Michipicoten) so soft as to be polished under the nail, and fall to pieces in water. G. $=2 \cdot 409$. Lustre resinous, Color pale apple-green, or yellowish. Streak greenish-white. Opaque to translucent.

Comp.-Q. ratio for $\mathrm{R}: \mathrm{Si}: \mathrm{H}=2: 3: 3$, or the same as for deweylite; formula $\mathrm{H}_{4}(\mathrm{Ni}$, $\mathrm{Mg})_{4} \mathrm{Si}_{3} \mathrm{O}_{12}$, being a nickel-gymnite. Analysis: Genth, Texas, Pa., $\mathrm{SiO}_{2} 35^{\circ} 36$, NiO $30 \cdot 64$, FeO $0 \cdot 24, \mathrm{MgO} 14 \cdot 60, \mathrm{CaO} 0 \cdot 26, \mathrm{H}_{2} \mathrm{O} 19 \cdot 09=100 \cdot 19$.

Pyr., etc.-In the closed uabe blackens and gives off water. B.B. infusible. With borax in O.F. gives a violet bead, becoming gray in R.F. (Nickel). Decomposed by hydrochloric acid without gelatinizing.

Obs.-From Texas, Lancaster Co., Pa., in thin crusts on chromic iron; from Webster, Jackson Co., N. G.; on Michipicoten Id., Lake Superior.

Alipite and Pimelite, an apple-green silicates containing some nickel. Garnierith and Noumeite, from New Caledonia are similar, and have been shown by Liversidge to be mixtures.

## Kaolinite Group.

## KAOLINITE.

Orthorhombic. $I \wedge I=120^{\circ}$. In rhombic, rhomboidal, or hexagonal scales or plates; sometimes in fan-shaped aggregations; usually constituting a clay-like mass, either compact, friable, or mealy; base of crystals lined, arising from the edges of snperimposed plates. Cleavage: basal, perfect. Twins: the hexagonal plates made up of six sectors.
$\mathrm{H}_{.}=1-2-5 . \quad \mathrm{G} .=2 \cdot 4-2 \cdot 63$. Lustre of plates pearly; of mass, pearly to dull earthy. Color white, grayish-white, yellowish, sometines brownish, blrish, or reddish. Scales transparent to translucent. Scales flexible, inelastic; usually unctuous and plastic.

Var.-1. Argilliform. Soft, clay-like; ordinary kaolinite; under the microscope, if not without, showing that it is made up largely of pearly scales. The constituent of most, if not
all, pure kaolin. 2. Fariniform. Mealy, hardly coherent, consisting of pearly augala scales. 3. Indurated; Lithomarge (Steinmark, Germ.). Firm and compact; H. $=2-2 \cdot 5$ When pulverized, often shows a scaly texture.

Comp.-Q. ratio for $\mathrm{R}: \mathrm{Si}: \mathrm{H}=3: 4: 2$; formula $\mathrm{AlSi}_{2} \mathrm{O}_{7}+2 \mathrm{aq}$, or making part of the water basic, $\mathrm{H}_{2} \mathrm{AlSi}_{2} \mathrm{O}_{8}+\mathrm{aq}=$ Silica $46 \cdot 4$, alumina $39 \cdot 7$, water $13 \cdot 9=100$.

Pyr., etc.-Yields water. B.B. infusible. Gives a blue color with cobalt solution. Insol0 ble in acids.

Diff.-Characterized by its unctuous, soapy feel ; alumina reaction B.B.
Obs.-Ordinary kaolin is a result of the decomposition of aluminous minerals, especially the feldspars of granitic and gneissoid rocks and porphyries. In some regions where these rucks have decomposed on a large scale, the resulting clay remains in vast beds of kaolin, usually more or less mixed with free quartz, and sometimes with oxide of iron from some of the other minerals present.

Occurs at Cache-Aprés in Belgium; also in Bohemia; in Saxony. At Yrieix, near Limoges, is the best locality of kaolin in Europe, it affords material for the famous Sèvres porcelain manufactory.
In the U. States, kaolin occurs at Newcastle and Wilmington, Del.; at various localities in the limonite region of Vermont (at Branford, etc.); Massachusetts ; Pennsylvania; Jacksonville, Ala.; Edgefield, S. C.; near Augusta, Ga.

Pholerite, Halloysite, clays allied to kaolinite.
Saponite.-A soft magnesian silicate; occurs in cavities in trap.

## Pinite Group.

## PINITE.

Amorphous; granular to cryptocrystalline; usually the latter. Also in crystals, and sometimes with cleavage, but only because psendomorphs, the form and cleavage being those of the minerals from which derived. Rarely a snbmicaceous cleavage, which may belong to the species.
$H .=2 \cdot 5-3 \cdot 5 . \quad$ G. $=2 \cdot 6-2 \cdot 85$. Lustre feeble, waxy. Color grayish-white, grayish-green, pea-green, dull green, brownish, reddish. Translucentopaque. Acts like a gum on polarized light; DesCl.

Comp., Var.-Pinite is essentially a hydrous alkaline silicate. Being a result of alteration, and amorphous, the mineral varies much in composition, and numerous species have been made of the mineral in its various conditions. The varieties of pinite here admitted agree closely in physical characters, and in the amount of potash and water present. Average composition : Silica 46, alumina 30 , potash 10 , water 6 ; formula (Ramm.) $\mathrm{H}_{6} \mathrm{~K}_{2} \mathrm{Al}_{2} \mathrm{Si}_{6} \mathrm{O}_{20}$. The mineral is related chemically, as it is also physically, to serpentine; and it is an alkali-alumina serpentine, as pyrophyllite is an alumina talc.

The different kinds are either pseudomorphous crystals after (1) iolite ; (2) nephelite; (3) scapolite; (4) some kind of feldspar ; (5) spodumene ; or (6) other aluminous mineral ; or (7) disseminated masses resembling indurated talc, steatite, lithomarge, or kaolinite, also a result of alteration; or (8) the prominent or sole constituent of a metamorphic rock, which is sometimes a pinite schist (analogous to, and often much resembling, talcose schist, and still more closely related to pyrophyllite schist). Some prominent varieties are:

Pinite. Speckstein [fr. the Pini mine at Aue, near Schneeberg]. Occurs in granite, and is supposed to be pseudomorphous after iolite.

GIESECKITE. In 6 -sided prisms, probably pseudomorphous after nephelite. $\mathrm{H}=3.5$. $G .=2 \cdot 78-2 \cdot 85$. Color grayish-green, olive-green, to brownish. Brought by Giesecké from Greenland. Also of similar characters from Diana, N. Y.
agalmatolite. Like ordinary massive pinite in its amorphous compact texture, lustre, and other physical characters, but contains more silica, so as to afford the formula of a bisilicate, or nearly, and it may be a distinct species. Agalmatolite was named from a $\alpha \lambda \mu \mu$, an image, and payodite from pagoda, the Chinese carving the soft stone into miniature pagodes

Images, etc. Part of the so-called agalmatolite of China is true pinite in composinon, auother part is compact pyrophyllite (p. 349), and still another steatite (p. 348).

Other minerals belonging in or near the pinite group are : dyssyntribite (=gieseckite) ; parophite; wilsonite; polyargite; rosite; killinite; giganto'ite; hygrophilite; gümbelits: restormelite. Also cataspilite; biharite; palagonite.

## Hydro-mica Group.

## FAHLUNITE.

In six- or twelve-sided prisms, but derived from pseudomorphism atter iolite. Clearage : basal sometimes perfect.
H. $=3 \cdot 5-5$. G. $=2 \cdot 6-2 \cdot 8$. Lustre of surface of basal cleavage pearly to waxy, glimmering. Color grayish-green, to greenish-brown, olive- or oilgreen; sometimes blackish-green to black ; streak colorless.


#### Abstract

Var.-This species is a result of alteration, and considerable variation in the results of analyses should be expected. The crystalline form is that of the original iolite, while the basal cleavage when distinct is that of the new species fahlunite. Comp.-Q ratio for $\mathrm{R}: \mathrm{R}: \mathrm{Si}: \mathrm{H}=1: 3: 5: 1$; whence the formula $\mathrm{H}_{4} \mathrm{R}_{2} \mathrm{R}_{2} \mathrm{Si}_{5} \mathrm{O}_{20}$, the water being considered as basic, and as entering to make up the deficiency of bases in the unisilicate. In some kinds, the same with the addition of $\mathrm{H}_{2} \mathrm{O}$. The Q . ratio of iolite, the original of the species, is $1: 3: 5$. Analysis by Wachtmeister, from Fahlun, $\mathrm{SiO}_{2} 44 \cdot 60$, $\mathrm{AlO}_{s} 30 \cdot 10, \mathrm{FeO} 3 \cdot 86, \mathrm{MnO} 2 \cdot 24, \mathrm{MgO} 6 \cdot 75, \mathrm{CaO} 1 \cdot 35, \mathrm{~K}_{2} \mathrm{O} 1 \cdot 98, \mathrm{H}_{2} \mathrm{O} 9 \cdot 35, \mathrm{~F} \operatorname{tr}=100 \cdot 23$.

Pyr., etc.-Yields water. B.B. fuses to a white blebby glass. Not acted upon by' acids. Pyrargillite is difficultly fusible, but is completely decomposed by hydrochloric acid.

Obs.-Fahlunite (and triclasite) from Fahlun, Sweden. The following are identical, or nearly so : Esmarkite and praseolite, Brevig; raumite, Raumo, Finland; chlorophyllite, Unity, Me.; pyrargillite, Helsingfors; polychroilite, Krageröe, and aspasiolite, Norway; huronite, Lakn Huron ( Weissite, Fahlun).


## MARGARODITE.

Like muscovite or common mica in crystallization, and in optical and other physical characters, except usually a more pearly lustre, and the color more commonly whitish or silvery.

Comp.-Q. ratio for R: $\mathrm{R}:$ Si $: \mathrm{H}$ mostly $1: 6: 9: 2$; whence the formula $\mathrm{H}_{c} \mathrm{R}_{2} \mathrm{Al}_{4} \mathrm{Si}_{9} \mathrm{O}_{36}$, the water being basic. Sometimes $Q$. ratio $1: 9: 12: 2$; but this division belongs with damourite, if the two are distinguishable. This species appears to be often, if not always, a result of the hydration of muscovite, there being all shades of gradation between it and that species. Muscovite has the Q. ratio for bases and silicon of $4: 5$, or nearly. Analysis, Smith and Brush, Litchfield, Ct., $\mathrm{SiO}_{2} 44 \cdot 60, \mathrm{Al}_{2} \mathrm{O}_{3} 36 \cdot 23, \mathrm{Fe}_{2} \mathrm{O}_{3} 1 \cdot 34, \mathrm{MgO} 0 \cdot 37, \mathrm{CaO} 0 \cdot 50, \mathrm{Na}_{2} \mathrm{O} 4 \cdot 10$, $\mathrm{K}_{2} \mathrm{O} 6 \cdot 20, \mathrm{H}_{2} \mathrm{O} 5 \cdot 26, \mathrm{~F}$ tr. $=100 \cdot 60$.

For pyrognostics and localities, see muscovite, p. 313.
Gilbertite.-Essentially identical with margarodite; tin mines, Saxony.

## DAMOURITE.

An aggregate of fine scales, mica-like in structure.
H. $=2-3$. G. $=2 \cdot 792$. Lustre pearly. Color yellow or yellowish-white Optic-axial divergence 10 to 12 degrees; for sterlingite $70^{\circ}$.

Comp.-A hydrous potash-mica, like margarodite, to which it is closely related. Q. ratio 23
for R: $\mathfrak{l l}:$ Si : H=1: $9: 12: 2$, or $1: 1$ for bases to silicon, if the water is basic. Formula $\mathrm{H}_{4} \mathrm{~K}_{2} \mathrm{Al}_{3} \mathrm{Si}_{6} \mathrm{O}_{24}$. Analysis, Monroe, from Sterling, Mass. (sterlingite), $\mathrm{SiO}_{2} 43 \cdot 87, \mathrm{AlO}_{3} 36 \cdot 45_{\text {; }}$ $\mathrm{FeO}_{3} 3 \cdot 36, \mathrm{~K}_{2} \mathrm{O} \quad 10 \cdot 86, \mathrm{H}_{2} \mathrm{O} \quad 5 \cdot 19=99 \cdot 73$.
It is the gangue of cyanite at Pontivy in Brittany; and the same at Horrsjöberg, Wermland. Associated with corundum in North Carolina; with spodumene, at Sterling, Mass.

## PARAGONITE. Pregrattite. Cossaite.

Massive, sometimes consisting distinctly of fine scales; the rock slaty or schistose. Cleavage of scales in one direction eminent, mica-like.
$\mathrm{H} .=2 \cdot 5-3 . \quad$ G. $=2 \cdot 779$, paragonite ; 2.895, pregrattite, Ellacher. Lustre strong pearly. Color yellowish, grayish, grayish-white, greenish, light applegreen. Trauslucent; single scales transparent.

Comp.-A hydrous sodium mica. Q. ratio for $\frac{1}{\mathrm{R}}: \mathrm{Z}: \mathrm{Si}: \mathrm{H}=1: 9: 12: 2$, or $1: 1$ for bases and silicon, if the water be made basic. Formula $\mathrm{H}_{4} \mathrm{Na}_{2} \mathrm{Al}_{3} \mathrm{Si}_{6} \mathrm{O}_{24}(\mathrm{~K}: \mathrm{Na}=1: 6)=$ Silica $46 \cdot 60$, alumina $39 \cdot 96$, soda $6 \cdot 90$, potash $1 \cdot 74$, water $4 \cdot 80=100$.
Pyr.-B.B. the paragonite is stated to be infusible. The pregrattite exfoliates somewhat like vermiculite (a property of some clinochlore and other species), and becomes milk-white on the edges.
Obs.-Paragonite constitutes the mass of the rock at Monte Campione, in the region of St. Gothard, containing cyanite and staurolite, called paragonitic or talcose schist. The pregrattite is from Pregratten in the Pusterthal, Tyrol; cossaite, from mines of Borgofranco, near Ivrea.
Ivigtite.-Occurs in yellow scales, also granular, with cryolite from Greenland.
EuṕHyllite.-Associated with tourmaline and corundum at Unionville, Penn. Q. ratio for $\mathrm{R}: \mathrm{fl}: \mathrm{Si}: \mathrm{H}=1: 8: 9: 2$. Average composition, Silica $41 \cdot 6$, alumina $42 \cdot 3$, lime $1 \cdot 5$, potash $3 \cdot 2$, soda $5 \cdot 9$, water $5 \cdot 5=100$.
Ephesite, Lesleyite.-Hydro-micas, perhaps identical with damourite. Occur with corundum, and impure from admixture with it.

Gllacherite.-A hydro-mica, containing 5 p. c. baryta. Pfitschthal, Tyrol.
Cookerte.-A hydrous lithium mica. From Hebron and Paris, Me., apparently a product of the alteration of rubellite.

## HISINGERITE.

Amorphous, compact, without cleavage.
$\mathrm{H} .=3$. G. $=3 \cdot 045$. Lustre greasy, inclining to vitreous. Color black to brownish-black. Streak yellowish-brown. Fracture conchoidal.

Comp.-Q. ratio for $\mathrm{R}+\mathrm{R}: \mathrm{Si}: \mathrm{H}=2: 3: 3$; formula $\mathrm{R}_{6} \mathrm{R}_{2} \mathrm{Si}_{3} \mathrm{O}_{18}+4$ aq (with one-third of the water basic). $\mathrm{R}=\mathrm{Fe}, \mathrm{H}_{2} ; \mathrm{R}=\mathrm{Fe}$. Analysis, Cleve, from Solberg, Norway, $\mathrm{SiO}_{2} 35.33$, $\mathrm{FeO}_{3} 32 \cdot 14, \mathrm{FeO} 7 \cdot 08, \mathrm{MgO} 3 \cdot 60, \mathrm{H}_{2} \mathrm{O} 22 \cdot 04=100 \cdot 19$.

Pyr., etc.-Yields much water. B B. fuses with difficulty to a black magnetic slag. With the fluxes gives reactions for iron. In hydrochloric acid easily decomposed without gelatinizing.

Obs.-Found at Longban, Tunaberg, Sweden; Riddarhyttan ; at Degerö (degeröite), near Helsingfors, Finland.

Ekmannite.-Foliated, also radiated. Cólor green, resembles chlorite. Analysis, Igelström, $\mathrm{SiO}_{2} 34 \cdot 50, \mathrm{FeO}_{3} 4 \cdot 97, \mathrm{FeO} 35 \cdot 78$, $\mathrm{MnO} 11 \cdot 45, \mathrm{MgO} 2 \cdot 99, \mathrm{H}_{2} \mathrm{O} \quad 10 \cdot 51=100$. With magnetite at Grythyttan, Sweden.

Neotocite.-Uncertain alteration-products of rhodonite; amorphous. vontains 20-30 p. c. MnO. Paisberg, near Filipstadt, Sweden; Finland, etc.

Gillingite; Sweden. Jollyte; Bodenmais, Bavaria.

## Vermiculite Group.*

The vermicultes have a micaceous structure. They are all unisilicates, having the general quantivalent ratio $R+\mathrm{m}: \mathrm{Si}: H=2: 2: 1$, the water being solely water of crystallization. The varieties differ in the ratio of the bases present in the protoxide and sesquioxide states.*

## JEFFERISITE.

Orthorhombic (?). In broad crystals or crystalline plates. Cleavage : basal eminent, affording easily very thin folia, like mica. Surface of plates often triangularly marked, by the crossing of lines at angles of $60^{\circ}$ and $120^{\circ}$.
$H .=1 \cdot 5$. G. $=2 \cdot 30$. Lustre pearly on cleavage surface. Color dark yellowish-brown and brownish-yellow ; light yellow by transmitted light. Transparent only in very thin folia. Flexible, almost brittle. Optically biaxial ; DesCl.

Comp.-Q. ratio for $\mathrm{R}: \mathrm{R}: \mathrm{Si}: \mathrm{H}=2: 3: 5: 2 \frac{1}{2}$, and $\mathrm{R}+\mathrm{R}: \mathrm{Si}: \mathrm{H}=2: 2: 1$; whence $\mathrm{R}_{4} \mathrm{R}_{2} \mathrm{Si}_{5} \mathrm{O}_{20}+5$ aq. Analysis: Brusb, Westchester, $\mathrm{SiO}_{2} 37 \cdot 10, \mathrm{AlO}_{3} 17 \cdot 57, \mathrm{FeO}_{3} 10 \cdot 54, \mathrm{FeO}$ $1 \cdot 26, \mathrm{MgO} 19 \cdot 65, \mathrm{CaO} 0 \cdot 56, \mathrm{Na}_{2} \mathrm{O}$ tr., $\mathrm{K}_{2} \mathrm{O} 0 \cdot 43, \mathrm{H}_{2} \mathrm{O} 13 \cdot 76=100 \cdot 87$.

Pyr., etc.-When heated to $300^{\circ} \mathrm{C}$. exfoliates very remarkably (like vermiculite) ; B.B. in forceps after exfoliation becomes pearly-white and opaque, and ultimately fuses to a dark gray mass. With the fluxes reactions for silica and iron. Decomposed by hydrochloric acid.

Obs.-Occurs in veins in serpentine at Westchester, Pa. Plates often several inches across.
Pyrosclerite. - Q. ratio for $\mathrm{R}: \mathrm{R}: \mathrm{Si}: \mathrm{H}=4: 2: 6: 3$, and for $\mathrm{R}+\mathrm{R}: \mathrm{Si}: \mathrm{H}=2: 2: 1$. Silica $38 \cdot 9$, alumina $14 \cdot 8$, magnesia $34 \cdot 6$, water $11 \cdot 7=100$. Color green. Elba. Chonicrite, also Elba, has the ratio $3: 2: 5: 2$.

Vermiculite.-Q. ratio for $\mathrm{R}: \mathrm{R}: \mathrm{Si}: \mathrm{H}=4: 2: 6: 3$. Milbury, Mass. Culsageeite. Q. ratio $R: R: S i: H=2: 1: 1: 1$. Jenk's mine. N. C. Hallite, same ratio=2:1:3:2. East Nottingham, Chester Co., Penn. Peliinamite, same ratio $=6: 4: 10: 5$. Pelham, Mass. Similar mineral from Lenni, Delaware Co., Pa., above ratio=6:4:10:5. In all of the above $\mathrm{R}=\mathrm{Mg}$ mostly, and $\mathrm{R}=\mathrm{Al}$ and $\mp \mathrm{e}$.

Kerrite.-Q. ratio $=6: 3: 10: 10$; and Maconite, Q. ratio $=3: 6: 8: 5$, are both from Culsagen mine, Macon Co., N. C. Vaalite, Q. ratio=6:3:10:4. South Africa.

Diabantite, Haves (diabantachronnyn, Liebe).-Fills cavities in amygdaloidal trap. Color dark green. Q. ratio for $\mathrm{R}: \mathrm{R}: \mathrm{Si}: \mathrm{H}=4: 2: 6: 3$, but iron a more prominent ingredient than in pyrosclerite (see above). Analysis : Hawes, Farmington, Ct., ${ }_{2}^{2} \mathrm{SiO}_{2} 33 \cdot 68, \mathrm{AlO}_{3}$ $10 \cdot 84, \mathrm{FeO}_{3} 2 \cdot 86, \mathrm{FeO} 24 \cdot 33, \mathrm{MnO} 0 \cdot 38, \mathrm{CaO} 0 \cdot 73, \mathrm{MgO} 16 \cdot 52, \mathrm{Na}_{2} \mathrm{O} 0 \cdot 33, \mathrm{H}_{2} \mathrm{O} 10 \cdot 02=99 \cdot 69$.

## Subsilicates.

## Chlorite Group.

## PENNINITE. Kämmererite.

Rhombohedral. $R \wedge R=65^{\circ} 36^{\prime}, \quad O \wedge R=103^{\circ} 55 ; \quad \dot{c}=3 \cdot 4951$. Cleavage; basal, highly perfect. Crystals often tabular, and in crested groups. Also massive, consisting of an aggregation of scales; also compact cryptocrystalline.

[^44]$\mathrm{H} .=2-2 \cdot 5 ; 3$, at times, on edges. G. $=2 \cdot 6-2 \cdot 85$. Lustre of clearage

652 653

 surface pearly ; of lateral plates vitreous, and sometimes brilliant. Color green, apple-green, grass. green, grayish-green, olive-green; also reddish, violet, rose-red, pink, grayish-red; occasionally yellowish and silver-white; violet crystals, and sometimes the green, hyacinth-red by transmitted light along the vertical axis. Transparent to subtranslucent. Laminæ flexible, not elastic. Double refraction feeble; axis either negative or positive, and sometimes positive and negative in different laminæ of the same plate or crystal.

Comp.-Q. ratio for bases and silicon $4: 3$, but varying from $4: 3$ to $5: 4$. Exact deductions from the analyses cannot be made until the state of oxidation of the iron in all cases is ascertained. Analysis: Schweizer, from Zermatt, $\mathrm{SiO}_{2} 33 \cdot 07, \mathrm{HlO}_{3} 9 \cdot 69, \mathrm{FeO} 11 \cdot 36, \mathrm{MgO}$ $32 \cdot 34, \mathrm{H}_{2} \mathrm{O} 12 \cdot 58=99 \cdot 08$.

Pyr., etc.- In the closed tube yields water. B.B. exfoliates somewhat and is difficultly fusible. With the fluxes all varieties give reactions for iron, and many varieties react for chromium. Partially decomposed by acids.

Obs.-Occurs with serpentine in the region of Zermatt, Valais, near Mt. Rosa; at Ala, Piedmont; at Schwarzenstein in the Tyrol; at Taberg in Wermland; at Snarum. Kümmererite is found near Miask in the Urals; at Haroldswick in Unst, Shetland Isles. Abundant at Texas, Lancaster Co., Pa., along with clinochlore, some crystals being imbedded in clinochlore, or the reverse.

The following names belong here: tabergite ; pstudophite, compact, massive (allophite); loganite.

Dolessite, euralite, aphrosiderite, chlorophcite are chloritic minerals, occurring under similar conditions, in amygdaloid, etc.

## RIPIDOLITE. Clinochlore. Klinochlor, Germ.

Monoclinic. $\quad C^{\gamma}=62^{\circ} 51^{\prime}=O \wedge i-i, \quad I \wedge I=125^{\circ} 37^{\prime}, O \wedge 4-i=108^{\circ}$ $14^{\prime} ; \quad c: b: a ̀=1 \times 47756:$

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Achmatovsk.

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Achmatovsk. $173195: 1$. Cleavage: $O$ eminent ; crystals often tabular, also oblong; frequently rhombohedral in aspect, the plane angles of the base being $60^{\circ}$ and $120^{\circ}$. Twins: twiming-plane ${ }^{3}$, making stellate groups, as in f. 656, 657, very common. Crystals often grouped in rosettes. Massive coarse scaly grannlar to fine granular and earthy.

$$
\mathrm{H} .=2-2 \cdot 5 . \mathrm{G} .=2 \cdot 65-2 \cdot 78
$$

Lustre of cleavage-face somewhat pearly. Color deep grass-green to olivegreen; also rose-red. Often strongly dichroic. Streak greenish-white to uncolored. Transparent to translucent. Flexible and somewhat elastic.

Comp.-Q. ratio for $\mathrm{R}: \mathrm{R}: \mathrm{Si}: \mathrm{H}=5: 3: 6: 4$; corresponding to $\mathrm{Mg}_{5} \mathrm{AlSi}_{3} \mathrm{O}_{14}+4 \mathrm{aq}=\mathbf{a}$ Silica $32 \cdot 5$, alumina $18 \%$, magnesia $36 \cdot 0$, water $12 \cdot 9=100$. Sometimes part of the $\mathbf{M g}$ is replaced by Fe .

Pyr., etc.-Yields water. B.B. in the platinum forceps whitens and fuses with difficulty on the edges to a grayish-black glass. With borax a clear glass colored by iron, and sometimes chromium. In sulphuric acid wholly decomposed. The variety from Willimantic. Ct., exfoliates in wormlike forms, like vermiculite.

Obs.-Occurs in connection with chloritic and talcose rocks or schist, and serpentine. Found at Achmatovsk; Schwarzenstein ;
 Zillerthal, etc. ; red (kotschubeite) in the district of Ufaleisk, Southern Ural; at Ala, Piedmont; at Zermatt; at Marienberg, Saxony. In the U. S., at Westchester and Unionville, and Texas, Pa. ; Brewster, N. Y.

Named ripidolite from $\rho \iota \pi \iota \varsigma, a$ fan, in allusion to a common mode of grouping of the crys. tals.

Levchtenbergite.-A prochlorite with the protoxide base almost wholly magnesia Slatoust, Urals.

## PROCHLORITE.

Hexagonal (?): Cleavage : basal, eminent. Crystals often implanted by their sides, and in divergent groups, fán-shaped, or spheroidal. Also in large folia. Massive granular.
$\mathrm{H} .=1-2$. G. $=2 \cdot 78-2 \cdot 96$. Translucent to opaque; transparent only in very thin folia. Lustre of cleavage surface feebly pearly. Color green, grass-green, olive-green, blackish-green ; across the axis by transmitted light sometimes red. Streak uncolored or greenish. Laminæ flexible, not elastic. Double refraction very weak; one optical negative
 axis (Dauphiny); or two very slightly diverging, apparently normal to plane of cleavage.

Comp.-Q. ratio for $\mathrm{R}: \mathrm{R}: \mathrm{Si}: \mathrm{H}=12: 9: 14: 9 \frac{1}{8}$; for bases and silicon 3:2. Average composition=Silica $26 \cdot 8$, alumina $19 \cdot 7$, iron protoxide $27 \cdot 5$, magnesia $15 \cdot 3$, water $10 \cdot 7=100$.

Pyr., etc.- Same as for ripidolite.
Obs.-Like other chlorites in mode of occurrence. Sometimes in implanted crystals, as at St. Gothard, etc. ; in the Zillerthal, Tyrol; Traversella in Piedmont; in Styria, Bohemia. Also massive in Cornwall, in tin veins (where it is called peach); at Arendal in Norway.

Cronstedtite.-Q. ratio $\mathrm{R}: \mathrm{Z}: \mathrm{Si}: \mathrm{H}=3: 3: 4: 3$. Przibram; Cornwall.
Strigovite.-Q. ratio=3:2:4:2. In granite of Striegan, Silesia. Grochauite same locality.

## MARGARITE. Perlglimmer, Germ.

Orthorhombic (?); hemihedral, with a monoclinic aspect. $\quad I \wedge I=119^{\circ}-$ $120^{\circ}$. Lateral planes horizontally striated. Cleavage: basal, eminent. Twins: common, composition-face $I$, and forming, by the crossing of 3 crystals, groups of 6 sectors. Usually in intersecting or aggregated laminæ; sometimes massive, with a scaly structure.
$H_{.}=3 \cdot 5-4 \cdot 5$. G. $=2 \cdot 99$, Hermann. Lustre of
 hase pearly, laterally vitreous. Color grayish, red-dish-white, yellowish. Translucent, subtranslucent. Laminæ rather brittle.

Optic-axial angle very obtuse; plane of axes parallel to the longer diagonal ; dispersion feeble.

Comp.-Q. ratio for $\mathrm{R}: \mathrm{R}: \mathrm{Si}: \mathrm{H}=1: 6: 4: 1$; whence, if the water be basic, for bases and silicon=2:1, formula RRSiO ${ }_{6}$; that is, $\mathrm{H}_{2} \mathrm{Ca}_{2} \mathrm{Hl}_{2} \mathrm{Si}_{2} \mathrm{O}_{12}$. Analysis, Smith, Chester, Mass., $\mathrm{SiO}_{2} 32 \cdot 21, \mathrm{AlO}_{3} 48.87, \mathrm{FeO}_{3} 2.50, \mathrm{MgO} 0.32, \mathrm{CaO} 10.02, \mathrm{Na}_{2} \mathrm{O}\left(\mathrm{K}_{2} \mathrm{O}\right) 1.91, \mathrm{H}_{2} \mathrm{O} 4.61, \mathrm{Li}_{2} \mathrm{O}$ $0 \cdot 32, \mathrm{MnO} 0 \cdot 20=100 \cdot 96$.

Pyr., etc.-Yields water in the closed tube. B.B. whitens and fuses on the edges.
Obs.-Margarite occurs in chlorite from the Greiner Mts.; near Sterzing in the Tyrol ; at different localities of emery in Asia Minor and the Grecian Archipelago; with corundum in Delaware Co., Pa.; at Unionville, Chester Co., Pa. (corundellite); in Madison Co. (clingmanite), and elsewhere in North Carolina; at the emery mines of Chester, Mass.

## CHLORITOID.

Monoclinic, or triclinic. $I \wedge I^{\prime}$ about $100^{\circ}$; $O$ (or cleavage surface) on lateral planes $93^{\circ}-95^{\circ}$, DesCl. Cleavage: basal perfect; parallel to a lateral plane imperfect. Usually coarsely foliated massive ; folia ofteı curved or bent, and brittle; also in thin scales or small plates disseminatec through the containing rock.
H. $=5 \cdot 5-6 . \quad$ G. $=3 \cdot 5-3 \cdot 6 . \quad$ Color dark gray, greenish-gray, greenishblack, grayish-black, often grass-green in very thin plates; strongly dichroic. Streak uncolored, or grayish, or very slightly greenish. Lustre of surface of cleavage somewhat pearly. Brittle.

Var.-1. The original chloritoid (or chloritspath) from Kossoibrod, near Katharinenburg in the Ural. 2. The Sismondine, from St. Marcel. 3. Masonite, from Natic, R. I., in very oroad plates of a dark grayish-green color. The Canada mineral is in small plates, one-fourth in. wide and half this thick, disseminated through a schist (like phyllite), and also in nodules of radiated structure, half an inch through. That of Gumuch-Dagh resembles sismondine, is dark green in thick folia and grass-green in very thin.

Comp.-Q. ratio for $\mathrm{R}: \mathrm{R}: \mathrm{Si}: \mathrm{H}=1: 3: 2: 1$, for most analyses. Analysis by v . Kobell, Bregratten, $\mathrm{SiO}_{2} 26 \cdot 19, \mathrm{AlO}_{3} 38 \cdot 30, \mathrm{FeO}_{3} 6 \cdot 00, \mathrm{FeO} 21 \cdot 11, \mathrm{MgO} 3 \cdot 30, \mathrm{H}_{2} \mathrm{O} 5 \cdot 50=100 \cdot 40$.

Pyr., etc - In a matrass yields water. B.B. nearly infusible; becomes darker and magnetic. Completely decomposed by sulphuric acid. The masonite fuses with difficulty to a dark green enamel.

Obs.-The Kossoibrod chloritoid is associated with mica and cyanite ; the St. Marcel occurs in a dark green chlorite schist, with garnets, magnetite, and pyrite; the Rhode Island, in an argillaceous schist ; the Chester, Mass., in talcose schist, with emery, diaspore, etc.

Phyllite (and ottrelite) closely resembles chloritoid, though the analyses hitherto made show a wide discrepancy, perhaps from want of purity in the material analyzed. Occurs in small, oblong, shining scales or plates, in àrgillaceous schist. Color blackish gray, greenish-gray, black. Phyllite occurs in the schist of Sterling, Goshen, Chesterfield, Plainfield, etc., in Massachusetts, and Newport, R. I. (neroportite). Ottrelite is from a similar rock near Ottrez.

Seybertite, -Orthorhombic. $l$ ^ $l=120^{\circ}$. In tabular crystals, sometimes hexagonal ; also foliated massive; sometimes lamellar radiate. Cleavage: basal perfect. Structure thin foliated, or micaceous parallel to the base. $\mathrm{H} .=4-5$. G. $=3-3 \cdot 1$. Lustre pearly submetallic: Color reddish-brown, yellowish, copper-red. Folia brittle. Analysis, Brush, Amity, $\mathrm{SiO}_{2}$ $20 \cdot 24, \mathrm{AlO}_{3} 39 \cdot 13, \mathrm{FeO}_{3} 3 \cdot 27, \mathrm{MgO} 20 \cdot 84, \mathrm{CaO} 13 \cdot 69, \mathrm{H}_{2} \mathrm{O} 1 \cdot 04, \mathrm{Na}_{2} \mathrm{O}\left(\mathrm{K}_{2} \mathrm{O} \cdot 1 \cdot 43, \mathrm{ZrO}_{2} 0 \cdot 75=\right.$ 100*39. Amity, N. Y. (clintonite) ; Fassathal (brandisite); Slatoust (xanthophyllite).

Corundormilite.-A chlorite with the $\mathbf{Q}$. ratio $=1: 1: 1: \frac{5}{6}$. Occurs with ccrundum at Asheville, N. C.; Chester, Mass.
Dudleyite.-Alteration product of margarite. Clay Co., N. C.; Dudleyville, Ala.
Willcoxite.-Near margarite. Decomposition product of corundum. Q. ratio for $\mathbf{R}: \mathbb{R}$ : $\mathrm{Si}: \mathrm{H}=3: 6: 5: 1$.

Thuringite.-Q. ratio 2:3:3:2. Contains principally iron (Fe and Fe). Hot Springs, Arkansas; Harper's Ferry (owoenite). Pattersonite from Unionville, Pa., near thuringite.

## 2. TANTALATES, COLUMBATES.

## PYROCHLORE.*

Isometric. Commonly in octahedrons. Cleavage: octahedral, some times distinct, especially in the smaller crystals.
$\mathrm{H}=5-5 \%$. G. $=4 \cdot 2-4 \cdot 35$. Lustre ritreous or resinous. Color brov/n, dark reddish- or blackish-brown. Streak light brown, yellowish-brown. Subtranslucent-opaque. Fracture conchoidal.

Comp.-A columbate of calcium, cerium, and other bases in varying amounts. Analigeis, by Rammelsberg. Brevig, $\mathrm{Cb}_{2} \mathrm{O}_{5} 58 \cdot 2 \pi, \mathrm{TiO}_{2} 5 \cdot 38, \mathrm{ThO}_{2} 4 \cdot 96$, $\mathrm{CeO} 5 \cdot 50$, $\mathrm{CaO} 10 \cdot 93, \mathrm{FeO}\left(\mathrm{JO}_{2}\right)$ $5 \cdot 53, \mathrm{Na}_{2} \mathrm{O} 5 \cdot 31, \mathrm{~F} 3 \cdot 75, \mathrm{H}_{2} \mathrm{O} \cdot \cdot 53=101 \cdot 16$.

Obs.-Occurs in syenite at Friederichsvärn and Laurvig, Norway; at Brevig; near Miask in the Urals; Kaiserstuhlgebirge in Breisgau (koppite) ; with samarskite in N. Carolina (G.= 4.794, chemical character unknown).

Microlite.*-In minute yellow octahedrons in feldspar. G. $=5.5$. Near pyrochlore, but probably containing more tantalum pentoxide. Chesterfield, Mass.

Pyrrifte. - In isometric octahedrons. Color orange-yellow. Chemical character unknown. From Mursinsk in the Ural. A mineral supposed to be similar from the Azores contains essentially, according to Hayes, columbium, zirconium, etc.

Azorite.-In minute tetragonal octahedrons resembling zircon. From the Azores in albito. Chemical character unknown.

## TANTALITE.*

Orthorhombic. Observed planes as in the figure. $I \wedge I=101^{\circ} 32^{\prime}$, $O \wedge 1-\bar{i}=122^{\circ} 3 \frac{1}{2}^{\prime} ; \dot{c}: \bar{b}: \check{a}=1 \cdot 5967: 1 \times 2247: 1$. $O \wedge$ $\frac{3}{2}-\imath=117^{\circ} 2^{\prime}, i-i \wedge 1-2=143^{\circ} 6 \frac{1}{2}, 1-2 \wedge 1-2$, adj., $=141^{\circ}$ $48^{\prime}, i-i \wedge i-\frac{9}{4}=118^{\circ} 33^{\prime}$. Twins: twinning-plane $i-\check{v}$, common. Also massive.
$\mathrm{H} .=6-6 \cdot 5 . \quad \mathrm{G} .=7-8$. Lustre nearly pure metallic, somewhat adamantine. Color iron-black. Streak red-dish-brown to black. Opaque. Brittle.

Comp., Var.-A tantalate either (1) of iron, or (2) of iron and manganese, or (3) a stanno-tantalate of these two bases. Formula $\mathrm{Fe}(\mathrm{Mn}) \mathrm{Ta}_{2} \mathrm{O}_{6}$. Sn is also often present (as $\mathrm{FeSnO}_{3}$, according to Rammelsberg), and some of the tantalum is often replaced by columbium. Analysis, Ramm., Tammela ( $\mathrm{G} .=7 \cdot 384$ ), $\mathrm{Ta}_{2} \mathrm{O}_{3} 76 \cdot 34, \mathrm{Cb}_{2} \mathrm{O}_{5} 7 \cdot 54$, $\mathrm{SnO}_{2} 0 \cdot 70 . \mathrm{FeO} 13 \cdot 90, \mathrm{MnO} 1 \cdot 42=99 \cdot 90$. Other varieties contain much
 naore $\mathrm{Cb}_{2} \mathrm{O}_{5}$, the kinds shade into one another.
Pyr., etc.-B.B. unaltered. With borax slowly dissolved, yielding an iron glass, which, at a certain point of saturation, gives, when treated in R.F. and subsequently flamed. a gray-ish-white bead; if completely saturated becomes of itself clonds on cooling. With salt of phosphorus dissolves slowly, giving an iron glass, which in R.F., if free from tungsten, is pale yellow on cooling ; treated with tin on charcoal it becomes green. If tungsten is present the bead is dark red, and is unchanged in color when treated with tin on charcoal. With soda and nitre gives a greenish-blue manganese reaction. On charcoal, with soda and suff. cient borax to dissolve the iron, gives in R.F. metallic tin. Decomposed on fusion with
potassium bisulphate in the platinum spoon, and gives on treatment with dilute hydrochlorio acid a yellow solution and a heavy white powder, which, on addition of metallic zinc, assumes a smalt-blue color ; on dilution with water the blue color soon disappears ( v . Kobell).
Obs.-Tantalite is confined mostly to albite or oligoclase granite, and is usually associated with beryl. Occurs in Finland, at several places ; in Sweden, in Fahlun, at Broddbo and Finbo; in France, at Chanteloube near Limoges, in pegmatite; in North Carolina.

Named T'antalite by Ekeberg. from the mythic Tantalus, in playful allusion to the difficulties (tantalizing) he encountered in his attempts to make a solution of the Finland mineral in acids.

## COLUMBITE.* Niobite. Ferroilmenite.

Orthorhombic. $I \wedge I=101^{\circ} 26^{\prime}, O \wedge 1-\bar{\imath}=134^{\circ} 53 \frac{1^{\prime}}{} ; \quad \dot{c}: \bar{b}: \check{a}=$ $1 \cdot 0038: 1 \cdot 2225: 1$. $O \wedge 1-\varkappa=140^{\circ} 36^{\prime}, \quad O \wedge 1-\frac{s}{z}=138^{\circ} 26^{\prime}, \quad i-\bar{\imath} \wedge 1-\frac{3}{}=$ $104^{\circ} 30^{\prime}, 1-\frac{3}{3} \wedge 1-\frac{3}{3}$, adj., $=151^{\circ}, i-\frac{3}{3} \wedge i-\frac{3}{3}$, ov. $i-\imath,=135^{\circ}{ }^{\circ} 40^{\prime}$, $i-\frac{2}{2} \wedge i-\overline{2}$, ov. $i-\bar{\eta}_{\text {, }}$ $=135^{\circ} 30^{\prime}$. Twins : twinning-plane 2- $-\hat{\imath}$. Cleavage: $i-\bar{i}$ and $i-\imath$, the former most distinct. Occurs also rarely massive.

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Haddam.
,62


Middletown, Conn.

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Greenland.
H. $=6$. G. $=5 \cdot 4-6 \cdot 5$. Lustre submetallic ; a little shining. Color ironblack, brownish-black, grayish-black; often iridescent. Streak dark red to black. Opaque. Fracture subconchoidal, uneven. Brittle.

Comp., Var.- $\mathrm{FeCb}_{2}\left(\mathrm{Ta}_{2}\right) \mathrm{O}_{8}$, with some manganese replacing part of the iron. The ratio of $\mathrm{Cb}:$ Ta generally $=3: 1$ (Bodenmais, Haddam), sometimes $4: 1,8: 1,10: 1$, etc.; in the Greenland columbite the $\mathrm{Ta}_{2} \mathrm{O}_{5}$ is almost entirely absent.

Analyses, Blomstrand, (1) Haddam (G. $=6 \cdot 15$ ), ( 2 ) Greenland ( $G .=5 \cdot 395$ ).

|  | $\mathrm{Cb}_{2} \mathrm{O}_{5}$ | $\mathrm{Ta}_{2} \mathrm{O}_{5}$ | $\mathrm{WO}_{3}$ | $\mathrm{SnO}_{2}$ | $\mathrm{ZrO}_{2}$ | FeO | MnO | $\mathrm{H}_{2} \mathrm{O}$ |
| :--- | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| (1) | 51.53 | 28.55 | 0.76 | 0.34 | 0.34 | 13.54 | 4.97 | $0.16=100.19$ |
| (2) | 77.97 | - | 0.13 | 0.73 | 0.13 | 17.33 | 3.51 | $-=99.80$ |

Pyr., etc.-Like tantalite. Von Kobell states that when decomposed by fusion with caustic potash, and treated with hydrochloric and sulphuric acids, it gives, on the addition of zinc, a blue color much more lasting than with tantalite; and the variety dianite, when similarly treated gives, on boiling with tin-foil, and dilution with its volume of water, sapphire-blue fluid, while, with tantalite and ordinary columbite, the metallic acid remains
undissolved. The variety from Haddam, undissolved. The variety from Haddam, Ct., is partially decomposed when the powdered mineral is evaporated to dryness with concentrated sulphuric acid, its color is changed to white, light gray, or yellow, and when boiled with hydrochloric acid and metallic zinc it gives a beantiful blue. The remarkably pure and unaltered columbite from Arksut-fiord in Greenland is also partially decomposed by sulphuric acid, and the product gives the reaction test witk zinc, as above.

Obs.-Occurs at Rabenstein, Bavaria; at Tirschenreuth, Bavaria; at Tammela in Finland; at Chanteloube, near Limoges; near Miask in the Ilmen Mts.; at Hermanskär, near Björskär, in Finland; in Greenland, at Evigtok.
in the United States, at Haddam, in a granite vein, and near Middletown, Conn. ; at Chesterfield, Mass. ; Standish, Me. ; Acworth, N. H. ; also Beverly, Mass.; Northfield, Mass. ; Plymouth, N. H. ; Greenfield, N. Y.

The Connecticut crystals are usually rather fragile from partial change; while those of Greenland and of Maine are very firm and hard.

Hermannolite (Shepard).-From the columbite locality at Haddam, Ct., and a variety of columbite due tc alteration. G. $=5 \% 35$. Supposed by Hermann to contain "ilmenium " pentoxide ( $\mathrm{Il}_{2} \mathrm{O}_{5}$ ).

TAPIOLITE.—Tetragonal. $\quad \dot{c}={ }^{6} 6464$ (rutile $\dot{c}={ }^{\circ} 6442$ ). $\quad \mathrm{FeTa}_{2}\left(\mathrm{Cb}_{2}\right) \mathrm{O}_{\mathrm{s}}$, with $\mathrm{Ta}: \mathrm{Cb}=4: 1$. Tammela, Finland.

Huelmite.-A stanno-tantalate of iron, uranium and yttrium. Massive. Color black. Near Fahlun, Sweden.

YTTROTANTALITE. Black Yttrotantalite.
Orthorhombic. $I \wedge I=123^{\circ} 10^{\prime} ; O \wedge 2-\bar{\imath}=103^{\circ} 26^{\prime} ; c \cdot \bar{b}: \check{u}=2 \cdot 093 \ddagger$ : 1-8482: 1. Crystals often tabular parallel to $i-\ell$. Also massive; amorphous.
H. $=5-5 \cdot 5 . \quad$ G. $=5 \cdot 4-5 \cdot 9$. Lustre submetallic to vitreous and greasy. Color black, brown. Streak gray to colorless. Opaque to subtranslucent. Fracture small conchoidal to granular.

Comp.-Mostly $\mathrm{R}_{2}(\mathrm{Ta}, \mathrm{Cb})_{2} \mathrm{O}_{7}$, with two equivalents of water, perhaps from alteration; $\mathrm{R}=\mathrm{Fe}: \mathrm{Ca}: \mathrm{Y}(\mathrm{Er}, \mathrm{Ce})=1: 2: 4$. Containing also $\mathrm{WO}_{3}$ and $\mathrm{SnO}_{2}$. Analysis (Ramm.), Ytterby, $\mathrm{Ta}_{2} \mathrm{O}_{0}$ $46 \cdot 25, \mathrm{Cb}_{2} \mathrm{O}_{5} 12 \cdot 32, \mathrm{SnO}_{2} 1 \cdot 12, \mathrm{WO}_{3} 2 \cdot 36, \mathrm{UO}_{2} 1 \cdot 61$, YO $10 \cdot 52$, ErO $6 \cdot 71$, $\mathrm{FeO} 3 \cdot 80$, $\mathrm{CeO} 2 \cdot 22$, $\mathrm{Ca} 5 \cdot 73, \mathrm{H}_{2} \mathrm{O} 6 \cdot 31=98.95$.

Pyr., etc.-In the closed tube yields water and turns yellow. On intense ignition becomes white. B.B. infusible. With salt of phosphorus dissolves with at first a separation of a white skeleton of tantalum pentoxide, which with a strong heat is also dissolved; the black variety from Ytterby gives a glass faintly tinted rose-red from the presence of tungsten. With soda and borax on charcoal gives traces of metallic tin (Berzelius). Not decomposed by acids. Decomposed on fusion with potassium bisulphate, and when the product is boiled with hydrychloric acid, metallic zinc gives a pale blue color to the solution which soon fades.

Obs.-Occurs in Sweden at Ytterby; at the Korarfvet mine, etc., near Fahlun.

## SAMARSKITE.* Uranotantalite.

Orthorhombic. $\quad I \wedge I=122^{\circ} 46^{\prime}$; $1 \cdot 833: 1$. Crystals often flattened parallel to $i-\frac{\nu}{\varepsilon}$, also less often to $i-\bar{z}$. Also in large irregular masses (N. Carolina). In flattened imbedded grains (Urals).
$\mathrm{H} .=5 \cdot 5-6 . \quad$ G. $=5 \cdot 614-5 \cdot 75 ; 5 \cdot 45$ $-5 \cdot 69$, North Carolina. Lustre of surface of fracture shining and submetallic. Color velvet-black. Streak dark reddish-brown. Opaque. Fracture subconchoidal.

Comp.-Analyses: 1. Allen (priv. contrib.); 2. Fiukener anil Stephans:


North Carolina

## 1. Mitchell

Co., N. C., $37.2018 .60-0.08-12.460 .7510 .90 \quad 4.25 \quad 14.45 \quad 0.55 \quad 1 \cdot 12=$ $\mathrm{UO}_{2}$
2. Miask, $\quad 47.47$ — $1.360 .05 \quad 6.05 \quad 4.35 \quad 10.950 .96 \quad 11.33+3.31 \quad 12.61 \quad 0.730 .45$
$\mathrm{MgO} 0 \cdot 14=99 \cdot 76$

* With LaO, DiO.
+ With $0 \because 25 \mathrm{CuO}$.
Pyr., etc.-In the closed tube decrepitates, glows like gadolinite, cracks open, and turns black, and is of diminished density. B.B. fuses on the edges to a black glass. With borax in O.F. gives a yellowish-green to red bead, in R.F. a yellow to greenish-black, which on flaming becomes opaque and yellowish-brown. With salt of phosphorus in both flames an emerald-green bead. With soda yields a manganese reaction. Decomposed on fusion with potassium bisulphate, yielding a yellow mass which on treatment with dilute hydrochloric acid separates white tantalic acid, and on boiling with metallic zinc gives a fine blue color. Samarskite in powder is also sufficiently decomposed on boiling with concentrated sulphuric acid to give the blue reduction test when the acid fluid is treated with metallic zinc or tin.

Obs.-Occurs in reddish-brown feldspar, near Miask in the Ural; the pieces having the size of hazel-nuts. In masses, sometimes weighing 20 lbs , in the decomposed feldspar of the mica mines of western North Carolina, especially in Mitchell Co. At both localities it is often intimately associated with columbite; at Miask the crystals of the latter species are sometimes implanted in parallel position upon those of the samarsizite.

Nohlite,-Near samarskite, but contains 4.62 p. c. water. Nohl, Sweden.

## EUXENITE.

Orthorhombic. Form a rectangular prism with lateral edges replaced, and a pyramid at summit. Cleavage none. Commonly massive.
$\mathrm{H} .=6 \cdot 5$. G. $=4 \cdot 60-4 \cdot 99$. Lustre brilliant, metallic-vitreous, or somewhat greasy. Color brownish-black; in thin splinters a reddish-brown translucence lighter than the streak. Streak-powder yellowish to reddishbrown. Fracture subconchoidal.

Comp.-According to Rammelsberg $2 \mathrm{RTiO}_{3}+\mathrm{RCb}_{2} \mathrm{O}_{6}+\mathrm{aq}$; here $\mathrm{R}=\mathrm{Y}, \mathrm{Fe}, \mathrm{U}$ mostly. Análysis, Ramm., Arendal, $\mathrm{Cb}_{2} \mathrm{O}_{5} 35 \cdot 09, \mathrm{TiO}_{2} 21 \cdot 16$, $\mathrm{YO} 27 \cdot 48$, $\mathrm{ErO} 3 \cdot 40, \mathrm{UO}_{2} 4 \cdot 78$, $\mathrm{CeO} 3 \cdot 17$, $\mathrm{FeO} 1 \cdot 38, \mathrm{H}_{2} \mathrm{O} \quad 2 \cdot 63=99 \cdot 63$.

Obs.-Occurs at Jölster in Norway ; near Tvedestrand ; at Alve, island of Tromoen, near Arendal; at Möretjär, near Naskilen.

Named by Scheerer from $\epsilon \check{\xi} \xi \in \nu 0 s$, a stranger, in allusion to the rarity of its occurrence.
巴scirynite.-Orthorhombic. H. $=5-6$. G. $=4 \cdot 9-5 \cdot 14$. Lustre submetallic to resinous, nearly dull. Color nearly black. Streak gray. Fracture small subconchoidal. Analysis, Ramm., $\mathrm{Cb}_{2} \mathrm{O}_{5} 28.81, \mathrm{TiO}_{2} 22.64, \mathrm{SnO}_{2} 0 \cdot 18, \mathrm{ThO}_{2} 15 \cdot 75, \mathrm{FeO} 3 \cdot 17, \mathrm{CeO} 18.49, \mathrm{LaO}(\mathrm{DiO})$ $5 \cdot 60$, YO $1 \cdot 12, \mathrm{CaO} 2 \cdot 75, \mathrm{H}_{2} \mathrm{O} 1 \cdot 07=99.58$. In feldspar with mica and zircon. Miask in the Urals.

Polymignite.-Orthorhombic. In slender crystals. $H=6 \cdot 5$. $G=4 \cdot 77-4 \cdot 85$. Lustre brilliant. Color black. Streak dark brown. Fracture perfect conchoidal Composition doubtful. Fredericksvärn, Norway. Perhaps identical with æschynite (Frankenheim).

Polycrase. - Orthorhombic. H. $=5 \cdot 5$. G. $=5 \cdot 09-5 \cdot 12$. Lustre bright. Color black. Streak grayish-brown. Fracture conchoidal. Analysis, Ramm., $\mathrm{Cb}_{2} \mathrm{O}_{5} 20.35, \mathrm{Ta}_{2} \mathrm{O}_{5} 4.00$, $\mathrm{TiO}_{2} 26 \cdot 59$, YO $23 \cdot 32, \mathrm{FeO} 2 \cdot 72, \mathrm{CeO} 2 \cdot 61, \mathrm{UO}_{2} 7 \cdot 70 \mathrm{H}_{2} \mathrm{O} 4 \cdot 02=98 \cdot 84$. In erystals in granite at Hitteröe, Norway.

Mengite.-Occurs in short prisms. $\quad \mathrm{H} .=5-5 \cdot 5$. G. $=5 \cdot 48$. Color iron-black. Contains zirconium, iron, titanium. In granite veins in the Ilmen Mts.
Rutherfordite.-Doubtful; contains titanium, cerium, etc. Rutherford Co., N. C.

FERGUSONITE.* Yellow Yttrotantalite. Tyrite. Bragite.
Tetragonal, hemihedral. $O \wedge 1-i=124^{\circ} 20^{\prime} ; \dot{c}=1 \cdot 464$. Cleavage: 1 in distinct traces.
$\mathrm{H}_{\mathrm{H}}=5 \cdot 5-6$. G. $=5 \cdot 838$, Allen; 5.800, Turner. Lustre externally dull, on the fracture brilliantly vitreous and submetallic. Color brownish-black; in thin scales pale liver-brown. Streak pale brown. Subtranslucent-opaque. Fracture imperfect conchoidal.

Comp.-According to Rammelsberg, essentially $\mathrm{R}_{3}(\mathrm{Cb}, \mathrm{Ta})_{2} \mathrm{O}_{8}$. Analysis, Ramm., Greenland, $\mathrm{Cb}_{2} \mathrm{O}_{5} 44.45, \mathrm{Ta}_{2} \mathrm{O}_{5} 6.30, \mathrm{SnO}_{2} 0.47$, $\mathrm{WO}_{3} 0 \cdot 15$, YO $24 \cdot 87$. $\mathrm{ErO} 9 \cdot 81$, $\mathrm{CeO} 7 \cdot 63(5 \cdot 63 \mathrm{LaO}, \mathrm{DiO}), \mathrm{UO}_{2} 2 \cdot 58$, $\mathrm{FeO} 0.74, \mathrm{CaO} 0 \cdot 61, \mathrm{H}_{2} \mathrm{O} 1 \cdot 49 \div 99 \cdot 10$. The amount of water varies from $1 \cdot 49-7$ p. c., and is regarded by Rammelsberg as arising from alteration.

Obs.-Fergusonite occurs near Cape Farewell in Greenland, disseminated in quartz. Also found at Ytterby, Sweden ; in Silesia. Bragite is from Helle, Alve, and elsewhere in Norway. Tyrite is associated with euxenite at Hampemyr on the island of Tromoe, and Helle on the mainland; at Næskul, about ten miles east of
 Arendal.

Kocimelite.-Near fergusonite. In yellow square-octahedrons and crusts in granite. Kochelwiesen, near Schreiberhau, Sllesia.
ADELPHOLITE.-A columbate of iron and manganese, containing 41.8 p . c. of metallic acids, and 9.7 p . c. of water. Tetragonal. H $=3 \cdot 5-4 \cdot 5$. $\quad \mathrm{G} .=3 \cdot 8$. Tammela, Finland.

## 3. PHOSPHATES, ARSENATES, VANADATES, ETU.

## Anhydrots Phosphates, Arsenates, etc.

## XENOTIME. Ytterspath, Germ.

Tetragonal. $\quad 0 \wedge 1=138^{\circ} 45^{\prime} ; \dot{c}=0 \cdot 6201.1 \wedge 1$, pyram., $=124^{\circ} 26^{\prime}$; basal, $=82^{\circ} 30^{\prime}$. Cleavage : I, perfect.

H. $=4-5$. G. $=4 \cdot 45-4 \cdot 56$. Lustre resinous. Color yellowish-brown, reddish-brown, hair-brown, flesh-red, grayish-white, pale yellow; streak pale brown, yellowish, or reddish. Opaque. Fracture meven and splintery.

Comp. $-\mathrm{Y}_{3} \mathrm{P}_{2} \mathrm{O}_{8}=$ Phosphorus pentoxide $\left(\mathrm{P}_{2} \mathrm{O}_{8}\right) 37 \cdot 87$, yttria $62 \cdot 13=100$.
Pyr., etc.-B.B. infusible. When moistened with sulphurio acid colors the flame bluish-green. Difficultly soluble in salt of phosphorus. Insoluble in acids.
Obs.-From a granite vein at Hitteröe ; at Ytterby, Sweden; St. Gothard; Binnenthal. In the U. S., in the gold washings of Clarksville, Georgia; in McDowell Co., N. C.; in the diamond sands of Bahia, Brazil. The wiserine of Kenugott has been shown by Klein to be octahedrite (vide p. 255).

Cryptolite (Phosphocerite).- $\mathrm{Ce}_{3} \mathrm{P}_{2} \mathrm{O}_{8}$ (with some Di), like monazite. Occurs in minute grains imbedded in apatite at Arendal; Siberia.

## Apatite Group.

## APATITE.*

Hexagonal ; often hemihedral. $O \wedge 1=139^{\circ} 41^{\prime} 38^{\prime \prime}$, Kokscharof ; $\dot{c}=$ $0 \cdot 734603$. $O \wedge 2-2=124^{\circ} 14 \frac{1_{2}^{\prime}}{}$. Cleavage: $O$, imperfect; $I$, more so. Also

globular and reniform, with a fibrous or imperfectly columnar structure, also massire, stı 'lcture granular.
H. $=5$, sometimes 4.5 when massive. G. $=2 \cdot 92-3 \cdot 25$. Lustre vitreous, inclining to subresinous. Streak white. Color usually sea-green, bluishgreen ; often violet-blue; sometimes white; occasionally yellow, gray, red, flesh-red, and brown; none bright. Transparent-opaque. A bluish opalescence sometimes in the direction of the vertical axis, especially in white varieties. Cross fracture conchoidal and uneven. Brittle.

Var.-1. Ordinary. Crystallized, or cleavable and granular massive. (a) The asparagus stone (originally from Murcia, Spain) and moroxite (from Arendal) are ordinary apatite. The former was yellowish-green, as the name implies; the latter was in greenish-blue and bluish crystals; and the names have been used for apatite of the same shades from other places. 2. Fibrous, concretionary, stalactitic. The name Phosphorite was used by Kirwan for all apatite, but in his mind it especially included the fibrous concretionary and partly scaly mineral from Estremadura, Spain, and elsewhere. 3. Fluor-apatite, Chlor-aputite. Apatite also varies as to the proportion of fluorine to chlorine, one of these elements sometimes replacing nearly or wholly the other.

Comp. -The formulas of the two varieties are $3 \mathrm{Ca}_{3} \mathrm{P}_{2} \mathrm{O}_{8}+\mathrm{CaCl}_{2}=$ Phosphorus pentoxide $40 \cdot 92$, lime $53 \cdot 80$, chlorine $6 \cdot 82=101 \cdot 54$; and $3 \mathrm{Ca}_{3} \mathrm{P}_{2} \mathrm{O}_{8}+\mathrm{CaF}_{2}=$ Phosphorus pentoxide 42.26 , lime 55.55 , fluorine $3 \cdot 77=101 \cdot 58$. Sometimes both calcium chloride $\left(\mathrm{CaCl}_{2}\right)$, and calciun fluoride ( $\mathrm{CaF}_{2}$ ), are present.

Pyr. etc.-B.B. in the forceps fuses with difficulty on the edges (F. $=4 \cdot 5-5$ ), coloring the flame reddish-yellow ; moistened with sulphuric acid and heated colors the flame pale bluishgreen (phosphoric acid) ; some varieties react for chlorine with salt of phosphorus, when the bead has been previously saturated with copper oxide, while others give fluorine when fused with this salt in an open glass tube. Gives a phosphide with the sodium test.
Dissolves in hydrochloric and nitric acid, yielding with sulphuric acid a copious precipitate of calcium sulphate ; the dilute nitric acid solution gives with lead acetate a white precipıtate, which B.B. on charcoal fuses, giving a globule.with crystalline facets on conling. Some varieties of apatite phosphoresce on heating.

Diff.-Characterized by its hexagonal form. Distinguished by its softness from beryl ; does not effervesce with acids like the carbonates; unlike pyromorphite, yields no lead B.B.

Obs.-Apatite occurs in rocks of various kinds and ages, but is most common in metamorphic crystalline rocks, especially in granular limestone, granitic and many metalliferous veins, particularly those of tin, in gneiss, syenite, hornblendic gneiss, mica schist, beds of iron ore; occasionally in serpentine, and in igneous or volcanic rocks; sometimes in ordinary stratified limestone, beds of sandstone or shale of the Silurian, Carboniferous, Jurassic, Cretaceous, or Tertiary formations; also in microscopic crystals in many igneous rocks, doleryte, etc. It has been observed as the petrifying material of wood.

Among its prominent localities are Ehrenfriedersdorf in Saxony; region of St. Gothard in Switzerland; Mussa-Alp in Piedmont; Untersulzbachthal and elsewhere in the Tyrol; Bohemia ; in England, in Cornwall. with tin ores; in Cumberland; in Devonshire; at Wheal Franco (francolite), etc. The variety, moroxite, occurs at Arendal, Snarum, etc., in Norway. The asparagus stone or Spargelstein of Jumilla, in Murcia, Spain. is pale yellowish-green in color; and a variety from Zillerthal is wine-yellow. The phosphorite, or massive radiated variety, is obtained abundantly near the junction of granite and argillyte, in Estremadura Spain; at Schlackenwald in Bohemia; at Krageröe, etc.

In Mass., at Norwich; at Bolton, and elsewhere. In New York, in St. Lawrence Co., in granular limestone ; in Rossie; Sanford mine, Essex Co.; near Edenville, Orange Co. In New Jersey, near Suckasunny, ; Mt. Pleasant mine, near Mt. Teabo ; at Hurdstown, Sussex Co. In Penn., at Leiperville, Delaware Co.; in Chester Co. In Delaware, at Dixon's quarry, Wilmington. In Canada, in North Elnsley, and passing into South Burgess; similar in Ross; at the foot of Calumet Falls; at St. Roch, on the Achigan.

Apatite was named by Werner from $\dot{\alpha} \pi \alpha \tau \alpha \dot{\alpha} \omega$, to deceive, older mineralogists having Leferred it to aquamarine, chrjeolite, amethyst, fluor, schorl, etc

Osteclite is massive impure altered apatite. The ordinary compact variety looks like lithographic stone of white to gray color. It also occurs earthy. Hauau.

GUANO.-Guano is bone-phosphate of calcium, or osteolite, mixed with the hydrous phosphate, brushite, and generally with some carbonate of calcium, and often a little magnesia, alumina, iron. silica, gypsum, and other impurities. It often contains 9 or 10 p . c. of water. It is often granular or oolitic ; also compact through consolidation produced by infiltrating waters, in which case it is frequently lamellar in structure, and also occasionally stalagmitic and stalactitic. Its colors are usually grayish-white, yellowish and dark brown, and somotimes reddish, and the lustre of a surface of fracture earthy to resinous.

Phosphatic Nodules. Coprolites.-Phosphatic nodules occur in many fossiliferous rocks, which are probably in all cases of organic origin. They sometimes present a spiral or other interior structure, derived from the animal organization that afforded them, and in such cases their coprolitic origin is unquestionable. In other cases there is no structure to aid in deciding whether they are true coprolites or not.

## PYROMORPHITE* Grünbleierz, Germ.

Hexagonal. Hemihedral. $0 \wedge 1=139^{\circ} 38^{\prime} ; \dot{c}=0.7362$. Cleavage : $I$ and 1 in traces. $I$ commonly striated horizontally. Often globular, reniform, and botryoidal or verruciform, with usually a subcolumnar structure; also fibrous, and granular.
H. $=3 \cdot 5-4 . \quad$ G. $=6 \cdot 5-7 \cdot 1$, mostly when without line ; 5-6.5, when containing lime. Lustre resinous. Color green, yellow, and brown, of different shades; sometimes wax-yellow and fine orange-yellow ; also grayishwhite to milk-white. Streak white, sometimes yellowish. Subtransparent -subtranslucent. Fracture subconchoidal, uneven. Brittle.

Comp.-Analogous to apatite, $3 \mathrm{~Pb}_{3} \mathrm{P}_{2} \mathrm{O}_{8}+\mathrm{PbCl}_{2}=$ Phosphorus pentoxide 15.71 , lead oxide $82 \cdot 27$, chlorine $2 \cdot 62=100 \cdot 60$. Some varieties contain arsenic replacing part of the phosphorus, and others calcium replacing the lead.
Pyr., etc.-In the closed tube gives a white sublimate of lead chloride. B.B. in the forceps fuses easily ( $\mathrm{F} .=15$ ), coloring the flame bluish-green; on charcoal fuses without reduction to a globule, which on cooling assumes a crystalline polyhedral form, while the coal is coated white from the chloride, and, nearer the assay, yellow from lead oxide. With soda on charcoal yields metallic lead; some varieties contain arsenic, and give the odor of garlic in R.F. on charcoal. With salt of phosphorus, previously saturated with copper oxide, gives an azureblue color to the flame when treated in O.F. (chlorine). Soluble in nitric acid.

Diff.-Characterized by its high specific gravity, and pyrognostics.
Obs.-Pyromorphite occurs principally in veins, and accompanies other ores of lead. Occurs in Saxony; at Przibram, Mies, and Bleistadt, in Bohemia; near Freiberg; Clausthal in the Harz; at Nassau; Beresof in Siberia; Cornwall, Derbyshire, and Cumberland, in England; Leadhills in Scotland; Wicklow, and elsewhere, Ireland. In the U. S. at Phenixville, Penn.; also in Maine, at Lubec and Lenox ; in Davidson Co., N. C.

The figures produced by etching (see p. 118) show that pyromorphite is hemihedral like apatite (Baumhauer).
Named from $\pi \dot{\nu} \rho$, fire, $\mu \circ \rho \phi \dot{n}$, form, alluding to the crystalline form the globule assumes on cooling.
mimetite.* Mimetesite.
Hexagonal. $O \wedge 1=139^{\circ} 58^{\prime} ; \dot{c}=0.7276$. Cleavage : 1 , imperfect. $\mathrm{H} .=3.5$. G. $=7 \cdot 0-7 \cdot 25$, mimetite; $5 \cdot 4-5 \cdot 5$, hedy-
 phane. Lustre resinous. Color pale yellow, passing into brown ; orange-yellow ; white or colorless. Streak white or nearly so. Subtransparent-transluceut.

Comp.-Formula $3 \mathrm{~Pb}_{3} \mathrm{As}_{2} \mathrm{O}_{8}+\mathrm{PbCl}_{2}=$ Arsenic pentoxide 23.20 , lead oxide $74 \cdot 96$, chlorine $2 \cdot 39=100 \%$. Generally part of the arsenic is replaced by phosphorus, and often the lead in part by calcium.
Pyr., etc.-In the closed tube like pyromorphite. B.B. fuses at 1, and on charcoal gives in R.F. an arsenical odor, and is easily reduced to metallic lead, coating the coal at first with lead chloride, and later with arsenous oxide and lead oxide. Gives the chlorine reactions as under pyromorphite. Soluble in nitric acid.
Obs.-Occurs at several of the mines in Cornwall; in Cumberland. At St. Prix in France, at Johanngeorgenstadt; at Nertschinsk, Siberia. At the Brookdale mine, Phenixville, Pa.

Mimetite is hemihedral like apatite and pyromorphite, as shown by etching (Baumhauer).
Named from $\mu \mu \eta \tau$ hs, imitator, it closely resembling pyromorphite.
HeDYPHANe.*-A variety containing much calcium. Campylite contains much lead phopphate.

## VANADINITE.*

Hexagonal. In smple hexagonal prisms, and prisms terminating in planes of the pyramids; $1 \wedge 1$, over terminal edge, $142^{\circ} 58^{\prime}, O \wedge 1=140^{\circ}$ $34^{\prime}, I \wedge 1=130^{\circ}$. Usually in implanted globules or incrustations.
$\mathrm{H} .=2 \cdot 75-3 . \quad \mathrm{G} .=6 \cdot 6623-7.23$. Lustre of surface of fracture resinous. Color light brownish-yellow, straw-yellow, reddish-brown. Streak white or yellowish. Subtranslucent-opaque. Fracture uneven, or flat conchoidal. Brittle.

Comp.-Formula $3 \mathrm{~Pb}_{3} \mathrm{~V}_{2} \mathrm{O}_{8}+\mathrm{PbCl}_{2}=$ Vanadium pentoxide $19 \cdot 36$, lead oxide $78 \cdot 70$ chlorine $2 \cdot 50=100 \cdot 56$.
Pyr., etc.-In the closed tube decrepitates and yields a faint white sublimate. B.B. fuses easily, and on charcoal to a black lustrous mass, which in R.F. yields metallic lead and a coating of chloride of lead; after completely oxidizing the lead in O.F the black residue gives with salt of phosphorus an emerald-green bead in R.F., which becomes light yellow in O.F. Gives the chlorine reaction with the copper test. Decomposed by hydrochloric acid.

If nitric acid be dropped on the crystals they become first deep red from the separation of vauadium pentoxide, and then yellow upon its solution.

Obs.-This mineral was first discovered at Zimapan in Mexico, by Del Rio. Since obtained at Wanlockhead in Dumfriesshire; aiso at Beresof in the Ural ; and near Kappel in Carinthia.

Dechenite. - $\mathrm{PbV}_{2} \mathrm{O}_{6}$ (or with some Zn ) $=$ Vanadium pentoxide $45 \cdot 1$, lead oxide $54.9=100$. Massive. Color deep red. Dahn, near Niederschlettenbach, Rhenish Bavaria. Freiberg in Breisgau (eusynckite).

Descloizite.*- $\mathrm{Pb}_{2} \mathrm{~V}_{2} \mathrm{O}_{7}=$ Vanadium pentoxide $29 \cdot 1$, lead oxide $70 \cdot 9=100$. Orthorhombic. South America. Wheatley Mine, Penn.

Pucherite (Frenzel).-Orthorhombic, near brookite in form (Websky). Occurs in small implanted crystals. Color reddish-brown. In composition a bismuth vanadate, $\mathrm{BiVO}_{4}=$ Vanadium pentoxide 28.3 , bismuth oxide $71 \%$ Pucher mine, Schneeberg, Saxony.

Roscoelite.-Occurs in thin micaceous scales, arranged in stellate or fan-shaped groups. Color dark brownish-green. Soft. G. $=2.938$ (Genth); 2.902 (Roscoe). Analyses: 1. Roscoe (Proc. Roy. Soc., May 10, 1876); 2. Genth (Am. J. Sci., July, 1876).

| 1. | $\begin{gathered} \mathrm{SiO}_{2} \\ 41 \cdot 25 \end{gathered}$ | $\begin{aligned} & \mathrm{V}_{2} \mathrm{O}_{5} \\ & 28.60 \end{aligned}$ | $\mathrm{AlO}_{3}$ | $\mathrm{FeO}_{3}$ | $\mathrm{MnO}_{3}$ | MgO | CaO | $\mathrm{K}_{2} \mathrm{O}$ | $\mathrm{Na}_{2} \mathrm{O} \quad \mathrm{H} . \mathrm{O}$ |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  |  |  |  | 1.15 | 2.01 | 0.61 |  | $\begin{aligned} & 0.82 \\ & 2.27=101.08 \end{aligned}$ |
| 2. | $47 \cdot 69$ | $22.02 \mathrm{~V}_{8} \mathrm{O}_{11}$ | $14 \cdot 10$ | 1.67 FeO | - | $2 \cdot 00$ | tı. | 7 7.59 | 0.19 ign. $4 \cdot 90$ |

The above analyses, made upon material derived from the same source, differ widely, especially in regard to the state of oxidation of the vanadium. Genth makes it $\mathrm{V}_{6} \mathrm{O}_{11}=$ $2 \mathrm{~V}_{2} \mathrm{O}_{3}, \mathrm{~V}_{2} \mathrm{O}_{\mathrm{s}}$. The formula given by Roscoe is $2 \mathrm{AlV}_{2} \mathrm{O}_{8}+\mathrm{K}_{4} \mathrm{Si}_{9} \mathrm{O}_{20} \div$ aq. Found in fissures in the porphyry, and in cavities in quartz at the gold mine at Granite Creek, El Dorado Co., Cai. Named by Dr. Blake, who discovered it. See further on p. 435.

## WAGNERITE.

Monoclinic. $\quad C=71^{\circ} 53^{\prime}, I \wedge I=95^{\circ} 25^{\prime}, O \wedge 1-\grave{\imath}=144^{\circ} 25^{\prime}$, B. \& M.; $\dot{c}: b: \grave{a}=0.78654: 1.045: 1$. Most of the prismatic planes deeply striated. Cleavage: $I$, and the orthodiagonal, imperfect; $O$ in traces.
$\mathrm{H} .=5-5 \cdot 5 . \quad \mathrm{G} .=3 \cdot 068$, transparent crystal ; 2.985, untransparent, Rammelsberg. Lustre vitreous. Streak white. Color yellow, of different shades; often grayish. Translucent. Fracture uneven and splintery across the prism.

Comp. $-\mathrm{Mg}_{3} \mathrm{P}_{2} \mathrm{O}_{8}+\mathrm{MgF}_{2}=$ Phosphorus pentoxide $43 \cdot 8$, magnesia $37 \cdot 1$, fluorine $11 \cdot 7$, magnesium $7 \cdot 4=100$.
$\boldsymbol{P y r}$., etc.-B.B. in the forceps fuses at 4 to a greenish-gray glass ; moistened with sulphuric acid colors the flame bluish-green. With borax reacts for iron. On fusion with soda effervesces, but is not completely dissolved; gives a faint manganese reaction. Fused with salt of phosphorus in an open glass tube reacts for fluorine. Soluble in nitric and hydrochloric acids. With sulphuric acid evolves fumes of fluohydric acid.

Obs.-Occurs in the valley of Höllgraben, near Werfen, in Salzburg, Austria.
KJERULFine ( $v$. Kobell).-Stands near wagnerite, but exact nature uncertain. In masses of a pale red color at Bamle, Norway.

## MONAZITE.*

Monoclinic. $\quad C=76^{\circ} 14^{\prime}, I \wedge I=93^{\circ} 10^{\prime}, O \wedge 1-\grave{\imath}=138^{\circ} 8^{\prime} ; \dot{c}: b: \grave{a}$ $=0.94715: 1.0265: 1$. Crys-

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Norwich, Ct.

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Watertown, Ct. tals usually flattened parallel to $i-i$. Cleavage: $O$ very perfect, and brilliant. Twins: twinning plane $O$.
$\mathrm{H} .=5-5 \cdot 5 . \quad$ G. $=4 \cdot 9-5 \cdot 26$. Lustre inclining to resinous. Color brownish-hyacinth-red, clove-brown, or jellowishbrown. Subtransparent-subtranslucent. Rather brittle.

Comp.-According to Rammelsberg, $5 \mathrm{R}_{3} \mathrm{P}_{2} \mathrm{O}_{8}+\mathrm{Th}_{2} \mathrm{P}_{2} \mathrm{O}_{9}$, where $\mathrm{R}=\mathrm{Ce}, \mathrm{La}$, Di. Analysis by Kersten, Slatoust,
$\mathrm{P}_{2} \mathrm{O}_{5} 28 \cdot 50, \mathrm{ThO}_{2} 17 \cdot 95, \mathrm{SnO}_{2} 2 \cdot 10, \mathrm{CeO} 26 \cdot 00, \mathrm{LaO} 23 \cdot 4 \mathrm{C}, \mathrm{MnO} 1 \cdot 86, \mathrm{CaO} 1 \cdot 68, \mathrm{~K}_{2} \mathrm{O}$ and $\mathrm{TiO}_{2}$ $t r .=101 \cdot 49$.
Pyr., etc:-B.B. infusible, turns gray, and when moistened with sulphuric acid colors the flame bluish-green. With borax gives a bead yellow while hot and colorless on cooling; a saturated bead becomes enamel-white on flaming. Difficultly soluble in hydrochloric acid.

Diff.-Its brilliant basal cleavage is a prominent character, distinguishing it from titanite.

Obs.-Monazite occurs near Slatoust in the Ilmen Mtn. ; also in the Ural ; near Nöterö in Norway; at Schreiberhau. In the United States, with sillimanite at Norwich ; at Yorktown, Westchester Co., N.Y.; near Crowder's Mountain, N. C.

Named from $\mu \circ v a ́ \zeta \omega$, to be solitary, in allusion to its rare occurrence.
Turnerite.-Identical with monazite, as first suggested by Prof. J. D. Dana. Occurs in minute yellow to brown crystals, rarely twins, at Mt. Sorel, Dauphing; Santa Brigritta, Tavetsch; Lercheltiny Alp, Binnenthal; Laacher See (v. Rath.). $\dot{c}: b: d=921696: 1$ : 0.958444 . $C .=77^{\circ} 18^{\prime}$ (Trechmann).

Korarfveite (Radominski).-A cerium phosphate containing fluorine; near monazite Occurs in large crystalline masses of a yellowish color at Korarfvet, near Fahlun, Sweden.

## TRIPHYLITE.* Triphyline.

Orthorhombic. $I \wedge I=98^{\circ}, O \wedge 1-\bar{\imath}=129^{\circ} 33^{\prime}$, Tschermak ; $\dot{c}: \bar{b}: \check{a}==$ $1 \cdot 211: 1 \cdot 1504: 1$. Faces of crystals usually uneven. Cleavage: $O$ nearly perfect in unaltered crystals. Massive.
$\mathrm{H} .=5$. G. $=3 \cdot 54-3 \cdot 6$. Subresinous. Color greenishgray; also bluish; often brownish-black externally. Streak grayish-white. Translucent in thin fragments.

Comp. $-\mathrm{R}_{3} \mathrm{P}_{2} \mathrm{O}_{8}$, where $\mathrm{R}=\mathrm{Fe}, \mathrm{Mn}$, (Ca) and $\mathrm{Li}_{2}\left(\mathrm{~K}_{2}, \mathrm{Na}_{2}\right)$. Analysis by Oesten, from Bodenmais, $\mathrm{P}_{2} \mathrm{O}_{5} 44 \cdot 19, \mathrm{FeO} 38 \cdot 21, \mathrm{MnO} 5 \cdot 63, \mathrm{MgO}$ $2 \cdot 39, \mathrm{CaO} 0 \cdot 76, \mathrm{Li}_{2} \mathrm{O} 7 \cdot 69, \mathrm{Na}_{2} \mathrm{O} 0 \cdot 7 \underline{1}, \mathrm{~K}_{2} \mathrm{O} 0 \cdot 04, \mathrm{SiO}_{2} 0 \cdot 40=100 \cdot 05$. The analyses vary much, owing to the impure material employed.

Pyr., etc.-In the closed tube sometimes decrepitates, turns to a


Norwich. dark colcr, and gives off traces of water. B.B. fuses at 1.5 , coloring the flame beautiful lithia-red in streaks, with a pale bluish-green on the exterior of the cone of flame. The coloration of the flame is best seen when the pulverized mineral, moistened with sulphuric acid, is treated on a loop of platinum wire. With borax gives an iron bead; with soda a reaction for manganese. Soluble in hydrochloric acid.

Obs.-Triphylite occurs at Rabenstein near Zwiesel in Bavaria; also at Keityö in Finland; Nor wich, Mass.

Named from $\tau \rho i s$, three-fold, and $\phi v \lambda \dot{\eta}$, family, in allusion to its containing three phosphates.

## TRIPLITE.* Zwieselite.

Orthorhombic. Imperfectly crystalline. Cleavage: unequal in three directions perpendicular to each other, one much the most distinct.
$\mathrm{H} .=5-5 \cdot 5$. G. $=3 \cdot 44-3.8$. Lustre resinous, inclining to adamantine. Color brown or blackish-brown to almost black. Streak yellowish-gray or brown. Subtranslucent-opaque. Fracture small conchoidal.

Comp. $-\mathrm{R}_{3} \mathrm{P}_{2} \mathrm{O}_{8}+\mathrm{RF}_{2} ; \mathrm{R}=\mathrm{Fe}, \mathrm{Mn}(\mathrm{Ca})$. Analysis, v . Kobell, Schlackenwald, $\mathrm{P}_{2} \mathrm{O}_{5} 33.85$, $\mathrm{FeO}_{3} 3 \cdot 50, \mathrm{FeO} 23 \cdot 38, \mathrm{MnO} 30 \cdot 00, \mathrm{CaO} 2 \cdot 20, \mathrm{MgO} 3 \cdot 05, \mathrm{~F}=8 \cdot 10=104^{\circ} 08$.

Pyr., etc.-B.B. fuses easily at 1.5 to a black magnetic globule; moistened with sulphuric acid colors the flame bluish-green. With borax in O.F. gives an amethystine colored glass (manganese) ; in R.F. a strong reaction for iron. With soda reacts for manganese. With sulphuric acid evolves fluohydric acid. Soluble in hydrochloric acid.

Obs.-Found by Alluaud at Limoges in France, with apatite; at Peilau in Silesia.
Zwieselite, a clove-brown variety, was found near Rabenstein, near Zwiesel in Bavaria, in quartz (G. $=3 \cdot 97$, Fuchs).

Sarcopside.-Near triplite. Valley of the Mühlbach, Silesia.

## AMBLYGONITE.*

Triclinic. Cleavage: $O$ perfect; $i-\bar{\imath}$ nearly perfect, angle between these cleavages $104 \frac{1}{2}^{\circ}$; also $I$ imperfect. Usually massive, cleavable; sometimes columnar.
$\mathrm{H}=6$. G. $=3-3 \cdot 11$. Lustre pearly on face of perfect cleavage $(O)$; vitreous on $i-i$, less perfect cleavage-face ; on cross-fracture a little greasy. Color pale mountain or sea-green, white, grayish, brownish-white. Sub-trunsparent-translucent. Fracture uneven. Optical axes very divergent; plane of axes nearly at right angles to $i-\bar{i}$; bisectrix of the acute angle negative, and parallel to the edge $8 / i \cdot \bar{i}$; DesCl.

Comp.-According to Rammelsberg, $2 \mathrm{AlP}_{2} \mathrm{O}_{8}+3 \mathrm{Li}(\mathrm{Na}) \mathrm{F}$. If $\mathrm{Na}: \mathrm{Li}=1: 4$, the fonxula requires: Phosphorus pentoxide $49 \cdot 24$, alumina $35 \cdot 58$, lithia $6 \cdot 24$, soda


Hebronite, Maine. $3 \cdot 23$, fluorine $9 \cdot 88=104 \cdot 17$.
Pyr., etc.-In the closed tube yields water, which at a high heat is acid and corrodes the glass. B.B. fuses easily at 2 , with intumescence, and becomes opaque-white on cooling. Colors the flame yellowish-red with traces of green; the Hebron variety gives an intense lithia-red, moistened with sulphuric acid gives a bluish-green to the Hame. With cobalt solution assumes a deep blue color (alumina). With borax and salt of phosphorus forms a transparent colorless glass. In fine powder dissolves easily in sulphuric acid, more slowly in hydrochloric.

Diff.-Distinguished by its easy fusibility; reaction for fluorine and lithia; greasy lustre in the mass, etc.

Obs.-Occurs at Chursdorf and Arnsdorf, near Penig in Saxony; also at Arendal, Norway. In the U. States, in Maine, at Hebron (hebronite), imbedded in a coarse granite with lepidolite, albite, quartz, red, green. and black tourmaline; also at Mt. Mica in Paris, 8 m . from Hebron, with tourmaline.

The name is from $\dot{a} \mu \beta \lambda \dot{v} s$, blunt, and $\gamma\langle v v$, angle.
Hebronite. - The mineral from Hebron, Me. (see above), has been shown by DesCloizeaux to differ in optical character ( $v>\rho$ ) from the Penig amblygonite. On this ground, as well as on account of a variation in the composition, it has been proposed ( v . Kobell) to make it a new species. The same optical character and composition belong to the mineral from Montebras (called montebrasite on the basis of an erroneous analysis). Analysis of hebronite, Pisani, $\mathrm{P}_{2} \mathrm{O}_{5} 46.65, \mathrm{AlO}_{3}$ $36 \cdot 00, \mathrm{Li}_{2} \mathrm{O} 9 \cdot 75, \mathrm{H}_{2} \mathrm{O} 4 \cdot 20, \mathrm{~F} 5 \cdot 22=101 \cdot 82$.

Herderite.-Supposed to be an anhydrous aluminum-calcium phosphate, with fluorine. Color yellowish-white. Ehrenfriedersdorf.

DURANGITE.-Monoclinic. Cleavage prismatic ( $110^{\circ} 10^{\prime}$ ). H. $=$ 5. G. $=3 \cdot 937-4 \cdot 07$. Color bright orange-red. Analysis, Hawes, Arsenic pentoxide $53 \cdot 11$, alumina $17 \cdot 19$, iron sesquioxide $9 \cdot 23$, manganese sesquioxide $2 \cdot 08$, soda $13 \cdot 06$, lithia $0 \cdot 65$, fluorine $7 \cdot 67=102 \cdot 99$. Formula $\mathrm{R}_{2} \mathrm{RAs}_{2} \mathrm{O}_{9}$ (with one-ninth of the oxygen replaced by fliuorine), or $\mathrm{RAs}_{2} \mathrm{O}_{8}+2 \mathrm{RF}$. Here $\mathrm{R}=\mathrm{Na}: \mathrm{Li}=10: 1 ; \mathrm{R}=\mathrm{Al}: \mathrm{Fe}: \mathrm{Hn}=15: 5: 1$. Other varieties, having a lighter color, have $\mathrm{Al}: \mathrm{Fe}=5: 1$. Occurs with cassiterite, near Durango, Mexico (Brush).

## Anhydrous Antimonates.

Monimoirte.-Mainly an antimonate of lead. Yellow. G.=5.94. Paisberg, Sweden.
Nadorite. $-\mathrm{PbSb}_{2} \mathrm{O}_{4}+\mathrm{PbCl}_{2}$. In yellow translucent crystals. $\mathrm{H} .=3$. G. $=7 \cdot 02$. DjebelNador, province of Constantine, Algiers.

Romeite. - An antimonate (or antimonite) of calcium. Occurs in groups of minute tetragonal crystals. Color yellow. St. Marcel, Piedmont.

Rivotrte.-Contains antimonic oxide, carbon dioxide, and copper. Amorphous. Colvy yellowish-green. Sierra del Cadi.

Stibioferrite.-Amorphous coating on stibnite, from Santa Clara Co., Cạl. Mixture (?).

Hrdrous Phosphates, Arsenates, etc.
PHARIMACOLITE.
Monoclinic. $I \wedge I=111^{\circ} 6^{\prime}, \quad i-\grave{\imath} \wedge i-2=109^{\circ} 26^{\prime}, 1 \wedge 1=117^{\circ} 24^{\prime}$. Cleavage: $i-i$ eminent. One of the faces 1 often obliterated by the exten sion of the other. Surfaces $i-i$ and $i-2$ usually striated parallel to thein mutual intersection. Rarely in crystals ; commonly in delicate silky fibres or acicular crystallizations, in stellated groups. Also botryoidal and stalac titic, and sometimes massive.
$\mathrm{H}==2-2 \cdot 5 . \quad \mathrm{G} .=2 \cdot 64-2 \cdot 73$. Lustre vitreous; on $i-\imath$ inclining to pearly Color white or grayish; frequently tinged red by arsenate of cobalt. Streak white. Trans-lucent-opaque. Fracture uneven. Thin lamiuæ flexible.

Comp. $-2 \mathrm{HCaAsO}_{4}+5 \mathrm{aq}=$ Arsenic pentoxide $51 \cdot 1$, lime $24 \cdot 9$, water $24 \cdot 0=160$.

Pyr., etc.-In the closed tube yields water and becomes opaque. B.B. in O.F. fuses with intumescence to a white
 enamel, and colors the flame light biue (arsenic). On charcoal in R.F. gives arsenical fumes, and fuses to a semi-transparent globule, scmetimes tinged blue from traces of cobalt. The ignited mineral reacts alkaline to test paper. Insoluble in water, but readily soluble in acids.

Obs.-Found with arsenical ores of cobalt and silver at Wittichen, Paden ; at Andreasberg, and at Riechelsdorf and Bieber; at Joarhimsthal.

This species was named. in allusion to its containing arsenic, from фá $\rho \mu \alpha \kappa \nu$, poison.
Struvite.-An ammonium-magnesium phosphate containirg 12 equivalents of water. In guano from Saldunha Bay, Africa.

Haidingerite.- $\mathrm{HCaAsO}_{4}+$ aq. $=$ Arsenic pentoxide $58 \cdot 1$, lime $28 \cdot 3$, water $13 \cdot 6=100$. Joachimsthal (?).

Brushite. - - $\mathrm{HCaPO}_{4}\left(\mathrm{R}_{3} \mathrm{P}_{2} \mathrm{O}_{8}\right)+2 \mathrm{aq}=$ Phosphorus pentoxide $41 \cdot 3$, lime $32 \cdot 6$, water $6 \cdot 1=$ 100. Monoclinic. G. $=2$ 208. On guano at Aves Island and Sombrero.

Metableshite.-2HCaPO 4 +3aq. G. $=2 \cdot 3$. Sombrero. Ornithrite. Probably altered brushite.

Chirnhite. $-\mathrm{R}_{3} \mathrm{P}_{2} \mathrm{O}_{8}+4 \mathrm{aq}$, with $\mathrm{R}=\mathrm{Ce}(\mathrm{Di}), \mathrm{Ca}$. Cornwall.
Wapplerite ( $F^{\top}$ renzel).-Triclinic. In minute crystals and in incrustations. Color white. Composition $\mathrm{H}(\mathrm{Ca}, \mathrm{Mg}) \mathrm{AsO}_{4}+7 \mathrm{aq}=(\mathrm{Ca}: \mathrm{Mg}=4: 3)$ arsenic pentoxide $48 \cdot 7$, lime $13 \cdot 5$, mag. nesia $7 \cdot 3$, water $30 \cdot 5=100$. Found with pharmacolite at Joachimsthal. Schrauf states that rasslerite is a pseudomorph after wapplerite.

Hernesite.-Monoclinic. Color snow-white. Composition $\mathrm{Mg}_{3} \mathrm{As}_{2} \mathrm{O}_{8}+8 \mathrm{aq}$. From the Banat.
Picrolifarmacolitf.-Monoclinic. $\mathrm{Ca}_{3}\left(\mathrm{Mg}_{8}\right) \mathrm{As}_{2} \mathrm{O}_{\mathbf{s}}+6$ aq. Riechelsdorf; Freiberg.

## VIVIANITE.

Monoclinic. $\quad C=75^{\circ} 34^{\prime}, I \wedge I=108^{\circ} 2^{\prime}, 1 \wedge 1=120^{\circ} 26^{\prime}, \dot{c}: b: a=$ $\cdot 935792: 1 \cdot 33369: 1$; v. Rath. Surface $i-\imath$ smooth, others striated. Cleavage: $i-i$, highly perfect ; $i-i$ and $\frac{1}{2}-i$ in traces. Often reuiform and globular. Structure divergent, fibrous, or earthy; also incrusting.
$\mathrm{H} .=1 \cdot 5-2$. G. $=2 \cdot 58-2 \cdot 68$. Lustre, $i-i$ pearly or metallic pearly; other faces vitreons. Color white or colorless, or nearly so, when unaltered ; often blue to green, decpening on exposure; usually green when seen perpendicularly to the cleavage-face, and blue transversely ; the two colors mingled, producing the ordinary dirty blue color. Streak colorless to bluish-white, soon changing to indigo-blue; color of the dry powder often liver-brown. Transparent-translucent; becoming opaque on exposure. Fracture not observable. Thin Iaminæ flexible. Sectile.


Comp. $-\mathrm{Fe}_{3} \mathrm{P}_{2} \mathrm{O}_{8}+8 \mathrm{aq}=$ Phosphorus pentoxide $28 \cdot 3$, iron protoxide $43 \cdot 0$, water $28 . \%=100$

Pyr., etc.-In the closed tube yields nentral water, whitens and exfoliates. B.13. fuses at $1 \cdot 5$, coloring the flame bluish-green, to a grayish-black magnetic globule. With the fluxes reacts for iron. Soluble in hydrochloric acid.

Diff.-Distinguishing characters : deep-blue color; softness; solubility in acid.
Obs.-Occurs associated with pyrrhotite and pyrite in copper and tin veins; in beds of clay, and sometimes associated with linonite, or bog iron ore; often in cavities of fossils or buried bones. Occurs at Wheal Falmouth, and elsewhere in Cornwall; in Devonshire, near Tavistock; at Bodenmais. The earthy variety, called blue iron earth or native Prussian blue occurs in Greenland, Carinthia, Cornwall, etc. At Cransac, France.

In N. America, it occurs in New Jersey, at Allentown; at Franklin. Also in Delaworre, near Middletown; near Cape Henlopen. In Maryland, in the north part of Somerset and Worcester Cos. 'In Virginio, in Stafford Co. In Canada, with limonite at Vandreuil, abundant.

Ludlamite (Field).-Monoclinic. H. $=3 \cdot 4$. G. $=3 \cdot 12$. Color clear green, from pale to dark. Transparent, brilliant. Composition $2 \mathrm{Fe}_{3} \mathrm{P}_{2} \mathrm{O}_{8}+\mathrm{H}_{2} \mathrm{FeO}_{2}+8 \mathrm{aq}=$ Phosphorus pentoxide $29 \cdot 88$, iron protoxide $53 \cdot 06$, water $17 \cdot 06=100$. Cornwall.

## ERYTHRITE. Cobalt Bloom. Kobaltblüthe, Germ.

Monoclinic. $\quad C=70^{\circ} 54^{\prime}, I \wedge I=111^{\circ} 16^{\prime} O \wedge 1-\grave{\imath}=146^{\circ} 19^{\prime} ; c: b: a ̀$ $=0.9747: 1.3818: 1$. Surfaces $i-i$ and $1-i$ vertically


Schneeberg. striated. Cleavage : $i-i$ highly perfect, $i-i$ and $1-i$ indistinct. Also in globular and reniform shapes, having a drusy surface and a columnar structure ; soinetimes stellate. Also pulverulent and earthy, incrusting.
$H .=1 \cdot 5-2 \cdot 5$; the lowest on $i-i . \quad$ G. $=2 \cdot 948$. Lustre of $i-i$ pearly; other faces adamantine, inclining to vitreous; also dull and earthy. Color crimson and peachred, sometimes pearl- or greenish-gray ; red tints incline to blue, perpendicular to cleavage-face. Streak a little paler than the color; the dry powder deep lavenderblue. Transparent-subtranslucent. Fracture not observable. Thin laminæ flexible in one direction. Sectile.
Comp. $-\mathrm{Co}_{3} \mathrm{As}_{2} \mathrm{O}_{8}+8 \mathrm{aq}=$ Arsenic pentoxide $38 \cdot 40$, cobalt oxide 37.56 , water 24.04 ; Co often partly replaced by $\mathrm{Fe}, \mathrm{Ca}$, or Ni .

Pyr., etc.-In the closed tube yields water at a gentle heat and turns bluish; at a higher heat gives off arsenous oxide, which condenses in crystals on the cool glass, and the residue has a dark gray or black color. B. B. in the forceps fuses at 2 to a gray bead, and colors the flame light blue (arsenic). B.B. on charcoal gives an arsenical odor, and fuses to a dark gray arsenide, which with borax gives the deep blue color characteristic of cobalt. Soluble in hydrochloric acid, giving a rose-red solution.

Obs.-Occurs at Schneeberg in Saxony; at Saalfeld in Thuringia; Wolfach and Wittichen in Baden; Modum in Norway; at Allemont in Dauphiny; in Cornwall, at the Botallack mine, etc.

Erythrite, when abundant, is valuable for the manufacture of smalt. Named from épvepós, red.

Roselite.*-Triclinic (Schrauf). Usually in complex twin crystals. H. $=3 \cdot 5$. G. $=3 \cdot 585$ -3. 738 . Color rose-red. Composition $\mathrm{R}_{3} \mathrm{As}_{2} \mathrm{O}_{8}+2 \mathrm{aq}$ (or 3 aq ), with $\mathrm{R}=\mathrm{Ca}, \mathrm{Mg}$, and Co. Analysis, Winkler, $\mathrm{As}_{2} \mathrm{O}_{5} 49 \cdot 96$, $\mathrm{CoO} 12 \cdot 45, \mathrm{CaO} 23^{\circ} 72$, $\mathrm{MgO} 4 \cdot 6^{\circ} 7, \mathrm{H}_{2} \mathrm{O} 9 \cdot 69=100 \cdot 49$. Found at Schneeberg, Saxony; the crystals from the Daniel Mine have a lighter color than those of the Rappold Mine, the latter containing less cobalt and more calcinm.

Winklerite.-Contains $\mathrm{As}_{2} \mathrm{O}_{5}, \mathrm{Cu}, \mathrm{Co}, \mathrm{Fe}, \mathrm{Co}, \mathrm{Ni}, \mathrm{Ca}, \mathrm{H}_{2} \mathrm{O}, \mathrm{CO}_{2}$, etc. Mixture(?). Pria, Spain.

Köttigite. - Near erythrite, but contains zinc. Schneeberg.
ANNABERGITE (Nickelblüthe, Germ.).- $\mathrm{Ni}_{3} \mathrm{As}_{2} \mathrm{O}_{8}+8 \mathrm{Paq}=$ Arsenic pentoxide $38 \cdot 6$, nickel oxide $37 \cdot 2$, water $24 \cdot 2=100$. Soft, earthy. Color apple-green. Allemont; Annaberg ; Riechelsdorf.

HUREAULITE.-A hydrous iron-manganese phosphate, occuring in cavities in triphylite at Limoges, France.

Chondrarsenite. - Yellow grains in barite; probably a manganese arsenate. Paisberg, Sweden.

## LIBETHENITE.

Urthorhombic. $I \wedge I=92^{\circ} 20^{\prime}, O \wedge 1-\bar{\imath}=143^{\circ} 50^{\prime} ; \dot{c}: b \quad \grave{a}=0 \cdot 7311$ $1 \cdot 0416: 1$. Crystals usually octahedral in aspect. Cleavage: diagonal, $i-\bar{\imath}, i-\check{\imath}$, very indistinct. Also globular or reniform, and compact.
H. $=4$. G. $=3 \cdot 6-3 \cdot 8$. Lustre resinous. Color olivegreen, generally dark. Streak olive-green. Translucent. to subtranslucent. Fracture subconchoidal-uneven. Brittle.

Comp. $-\mathrm{Cu}_{4} \mathrm{P}_{2} \mathrm{O}_{9}+$ aq, or $\mathrm{Cu}_{3} \mathrm{P}_{2} \mathrm{O}_{8}+\mathrm{H}_{2} \mathrm{CuO}_{2}$ (Ramm.) $=$ Phosphorus pentoxide $29 \cdot 7$, copper oxide $66 \cdot 5$, water $3 \cdot 8=100$.

Pyr., etc.-In the closed tube yields water and turns black. B.B. fuses at 2 and colors the flame emerald-green. On charcoal with soda gives metallic copper, sometimes also an arsenical odor. Fused with

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 metallic lead on charcoal is reduced to metallic copper, with the formation of lead phosphate, which treated in R.F. gives a crystalline polyhedral bead on cooling. With the fluxes reacts for copper. Soluble in nitric acid.

Obs.-Occurs at Libethen, in Hungary ; at Rheinbreitenbach and Ehl on the Rhine; at Nischne Tagilsk in the Ural ; in Bolivia; Chili.

## OLIVENITE.

Orthorhombic. $I \wedge I=92^{\circ} 30^{\prime}, O \wedge 1-\bar{\imath}=144^{\circ} 14^{\prime} ; c: \bar{b}: \check{a}=0 \cdot 72$ $1 \cdot 0446$ : 1. Cleavage: $I$ and $1-\tau$ in traces. Sometimes acicular. Also globular and reniform, indistinctly fibrous, fibres straight and divergent, rarely promiscuous; also curved lamellar and granular.
$\mathrm{H} .=3 . \quad \mathrm{G} .=4 \cdot 1-4 \cdot 4 . \quad$ Lustre adamantine-vitreous; of some fibrous varieties pearly. Color various shades of olivegreen, passing into leek-, siskin-, pistachio-, and blackishgreen; also liver- and wood-brown; sometimes straw-yellow and grayish-white. Streak olive-green-brown. Subtrans-parent-opaque. Fracture, when observable, conchoidaluneven. Brittle.


Comp. $-\mathrm{Cu}_{4} \mathrm{As}_{2} \mathrm{O}_{3}+\mathrm{aq}=\mathrm{Cu}_{3} \mathrm{As}_{2} \mathrm{O}_{8}+\mathrm{H}_{2} \mathrm{CuO}_{2}$ (Ramm.) = Arsenic pentoxide $40 \cdot 66$, copper oxide $56 \cdot 15$, water $3 \cdot 19=100$.

Pyr., etc.-In the closed tube gives water. B.B. fuses at 2, coloring the flame bluish-green, and on cooling the fused mass appears crystalline. B. B. on charcoal fuses with deflagration, gives off arsenical fumes, and yields a metallic arsenide, which, with soda yields a globule of copper. With the fluxes reacts for copper. Soluble in nitric acid.

Obs.-The crystallized varieties occur in many of the Cornwall mines; near Tavistock in Devonshire; also at Alston Moor in Cumberland ; at Camsdorf and Saalfeld in Thuringia; the Tyrol; the Banat; Siberia; Chili ; and other places.

ADAMITE.- $\mathrm{Zn}_{3} \mathrm{As}_{2} \mathrm{O}_{8}+\mathrm{H}_{2} \mathrm{ZnO}_{2}=$ Arsenic pentoxide $40 \cdot 2$, zinc oxide 56.7 , water $3 \cdot 1=100$. Color yellow. Chanarcillo, Chili; Cap Garonne.
Tagilite $-\mathrm{Cu}_{4} \mathrm{P}_{2} \mathrm{O}_{9}+3 \mathrm{aq}\left(=\mathrm{Cu}_{3} \mathrm{P}_{2} \mathrm{O}_{8}+\mathrm{H}_{2} \mathrm{CuO}_{2}+2 \mathrm{aq}\right.$ ). Color emerald-green. NischneTagilsk. Isoclasite. $\mathrm{Ca}_{4} \mathrm{P}_{2} \mathrm{O}_{3}+5 \mathrm{aq}\left(=\mathrm{Ca}_{3} \mathrm{P}_{2} \mathrm{O}_{8}+\mathrm{H}_{2} \mathrm{CaO}_{2}+\right.$ taq $)$. Colorless to snow-white. Joachimsthal.

Euchroire. - $\mathrm{Cu}_{3} \mathrm{As}_{2} \mathrm{O}_{8}+\mathrm{H}_{2} \mathrm{CuO}_{2}+6 \mathrm{aq}$ (Ramm.) =Arsenic pentoxide $34 \cdot 1$, copper oxide 47\%, ซater $18 \%=100$. Color emerald-green. Libethen, Hungary.

Chtorotile.- $\mathrm{Cu}_{3} \mathrm{As}_{2} \mathrm{O}_{8}+6 \mathrm{aq}$. In capillary crystals. Also fibrous; massive. ('olor applegreen. In quartz at Schneeberg and Zinnwald; Thuringia; Chili (Frenzel).
Veszenfite (Schrauf).-A hydrous copper phosphate; composition $4 \mathrm{Cu}_{3} \mathrm{P}_{2} \mathrm{O}_{8}+5 \mathrm{aq}$. Triclinic. Occurs in crystalline crusts on a garnet-rock at Morawicza in the Banat.

## LIROCONITE. Linsenerz, Germ.

Monoclinic. $I \wedge I=74^{\circ} 21^{\prime}$, DesCl. $C=88^{\circ} 33^{\prime}$. Cleavage lateral, but obtained with difficulty. Rarely granular.
H. $=2-2 \cdot j$. G. $=2 \cdot 88-2 \cdot 98$. Lustre vitreous, inclining to resinous. Color and streak sky-blue-verdigris-green. Fracture imperfectly conchoidal, uneven. Imperfectly sectile.

Comp.-Formula $\mathrm{Cu}_{3}(\mathrm{tl}) \mathrm{As}_{2}\left(\mathrm{P}_{2}\right) \mathrm{O}_{8}+\mathrm{H}_{6}\left(\mathrm{Cu}_{3}, \mathrm{Al}\right) \mathrm{O}_{6}+9$ aq, with $\mathrm{Cu}_{3}: \mathrm{Al}=3: 2$, and As : $\mathbf{P}=1: 4$. This requires arsenic pentoxide $23 \cdot 1$, phosphorus pentoxide $3 \cdot 6$, copper oxide $35 \cdot 9$, alumina $10 \cdot 3$, water $27 \cdot 1=100$.

Pyr., etc.-In the closed tube gives much water and turns olive-green. B.B. cracks open, but does not decrepitate; fuses less readily than olivenite to a dark gray slag; on charcoal cracks open, deflagrates, and gives reactions like olivenite. Soluble in nitric acid.

Obs.-With various ores of copper, pyrite, and quartz, at Wheal Gorland, Wheal Muttrell, etc., in Cornwall; also in minute crystals at Herrengrund in Hungary ; and in Voigtland.

Pseudomalachite Phosphochalcite. - $\mathrm{Cu}_{6} \mathrm{P}_{2} \mathrm{O}_{11}+3 \mathrm{aq}=\mathrm{Cu}_{3} \mathrm{P}_{2} \mathrm{O}_{8}+3 \mathrm{H}_{2} \mathrm{CuO}_{2}=\mathrm{P}_{2} \mathrm{O}_{5} 21 \mathrm{1}$, $\mathrm{CuO} 70 \cdot 9, \mathrm{H}_{2} \mathrm{O} \quad 8 \cdot 0=100$. Triclinic (Schrauf). G. $=4 \% 34$. Color emerald-green. Related sub-species: Ehlite (Prasine), $\mathrm{Cu}_{3} \mathrm{P}_{2} \mathrm{O}_{8}+2 \mathrm{H}_{2} \mathrm{CuO}_{2}+\mathrm{aq}$ (Ramm.); Difydite, $\mathrm{Cu}_{3} \mathrm{P}_{2} \mathrm{O}_{8}+$ $2 \mathrm{H}_{2} \mathrm{CuO}_{2}$. Ehl, near Linz, on the Rhine; Libethen, Hungary; Nischne Tagilsk; Cornwall.

Erinite.- $\mathrm{Cu}_{3} \mathrm{As}_{2} \mathrm{O}_{8}+2 \mathrm{H}_{2} \mathrm{CuO}_{\%}$. In mammillated crystalline groups. Color green. Cornwall.

Cornwallite.- $\mathrm{Cu}_{5} \mathrm{As}_{2} \mathrm{O}_{10}+3 \mathrm{aq}\left(=\mathrm{Cu}_{3} \mathrm{As}_{2} \mathrm{O}_{8}+2 \mathrm{H}_{2} \mathrm{CuO}_{2}+\mathrm{aq}\right)$. Amorphous. Color green. Cornwall (Church).

Psittacinite.-Occurs in thin crypto-crystalline coatings, sometimes having a bntryoidal structure; also pulverulent. Color siskin green to olive green. Formula $2 \mathrm{R}_{3} \mathrm{~V}_{2} \mathrm{O}_{8}+3 \mathrm{H}_{2} \mathrm{CuO}_{2}$ +6 aq , with $\mathrm{R}=\mathrm{Pb}: \mathrm{Cu}=3: 1$. This requires: Vanadium pentoxide $19 \cdot 32$, lead oxide $53 \cdot 15$, copper oxide $18 \cdot 95$, water $8.58=100$. Found at the gold mines in Silver Star District, Montana (Genth. Am. J. Sci., III., xii., 35, 1876).

Mottramite.-Occurs as a thin crystalline incrustation, which is sometimes velvety, consisting of minute crystals; more generally compact. H. $=3$. G. $=5.894$. Color black by reflected light, in thin particles yellowish, translucent (crystals) ; purplish-brown, opaque, (compact). Formula $(\mathrm{Pb}, \mathrm{Cu})_{3} \mathrm{~V}_{2} \mathrm{O}_{8}+2 \mathrm{H}_{2}(\mathrm{~Pb}, \mathrm{Cu}) \mathrm{O}_{2}$, which requires vanadium pentoxide $18 . \% 4$, copper oxide $20 \cdot 39$, lead oxide $57 \cdot 18$, water $3 \cdot 69=100$. Related to dihydrite and arinite. Found in Keuper sandstone at Alderley Edge and Mottram St. Andrew's, in Cheshire, England (Roscoe, Proc. Roy. Soc., xxv., III., 1876).
Volborthite. $-\mathrm{R}_{4} \mathrm{~V}_{2} \mathrm{O}_{3}+\mathrm{aq}$, with $\mathrm{R}=\mathrm{Ca}: \mathrm{Cu}=2: 3$ (or $3: 7$ ), Ramm. From the Urals, Kalk-volborthit (Germ.), Friedrichsrode, contains calcium.

CLINOCLASITE. Strahlerz. Germ.
Monoclinic. $C^{\gamma}=80^{\circ} 30^{\prime}, I \wedge I$, front, $=56^{\circ}$. Cleavage : basal, highly

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Color pale apple-green. perfect. Also massive, hemispherical, or reniform; structure tadated fibrous.
$\mathrm{H} .=2 \cdot 5-3 . \quad G .=4 \cdot 19-4 \cdot 36$. Lustre: $O$ pearly; elsewhere vitreons to resinons. Color internally dark verdigris-green; externally blackish-blne green. Streak bluish-green. Subtranslucent. Not very brittle.

Comp. - $\mathrm{Cu}_{3} \mathrm{As}_{2} \mathrm{O}_{4}+3 \mathrm{H}_{2} \mathrm{CuO}_{2}=$ Arsenic pentoxide $30 \cdot 2$, conper oxide $62 \cdot 7$, water $71=100$.
Fyr., etc.-Same as for olivenite.
Obs.-Occurs in Cornwall, with other ores of copper, at several mines. Also found in the Erzgebirge

Tyrolite (Kupferschaum).-A hydrous arsenate of copper (Cu. $\mathrm{As}_{2} \mathrm{O}_{10}+n$ aq), containing also culcium carbonate (as an impurity ?) Libelhen, Hungary; Schneeberg, etc.

Chalcophyllite (Copper mica; Kupferglimmer, Germ.) - $-\mathrm{Cu}_{3} \mathrm{As}_{2} \mathrm{O}_{8}+5 \mathrm{H}_{2} \mathrm{CuO}_{2}+7 \mathrm{H}_{2} \mathrm{O}=$ Arsenic pentoxide $21 \%$, copper oxide $58 \%$, water $20.0=100$. Copper mines of Cornwall, Hungary; Moldawa.
$x_{\text {lazulite. }}$ Blauspath, Germ.
Monoclinic. $C=88^{\circ} 15^{\prime}, I \wedge I=91^{\circ} 30^{\prime}, O \wedge 1-\grave{\imath}=139^{\circ} 45^{\prime}$, Prüfer ; $\dot{c}: b: \grave{a}=0 \cdot 86904: 1 \cdot 0260: 1$. Twins: twinning-plane $i \cdot i ;$ also $O$. Cleavage: lateral, indistinct. Also massive.


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H. $=5-6$. G. $=3.0557$, Fuchs Lustre vitreous. Color azure-blue; commonly a fine deep blue viewed along one axis, and a pale greenish-blue along another. Streak white. - Subtranslucent-opaque. Fracture uneven. Brittle.

Comp. $-\mathrm{RAlP}_{2} \mathrm{O}_{9}+\mathrm{aq}=\mathrm{HlP}_{2} \mathrm{O}_{8}+\mathrm{H}_{2}(\mathrm{Mg}, \mathrm{Fe}) \mathrm{O}_{2}(\mathrm{Dana})=$ Phosphorus pentoxide $46 \cdot 8$, alu mina $34 \cdot 0$, magnesia $13 \cdot 2$, water $6 \cdot 0=100$.

Pyr., etc.-In the closed tube whitens and yields water. B.B. with cobalt solution the blue color of the mineral is restored. In the forceps whitens, cracks open, swells up, and without fusion falls to pieces, coloring the flame bluish-green. The green color is made more intense by moistening the assay with sulphuric acid. With the fluxes gives an iron glass; with soda on charcoal an infusible mass. Unacted upon by acids, retaining perfectly its blue color.
Diff.-Characterized by its fine blue color; blue flame B.B.
Obs.-Occurs near Werfen in Salzburg; in Gratz, near Vorau ; in Krieglach, in Styria; at Hochthäligrat, at the Gorner glacier, in Switzerland ; in Horrsjöberg, Wermland ; Westara, Sweden; also at Tijuco in Minas Geraes. Brazil. Abundant at Crowder's Mt., Lincoln Co., N. C.; and on Graves Mt., Lincoln Co., Ga., 50 m . above Augusta.

## SCORODITE.

Orthorhombic. $I \wedge I=98^{\circ} 2^{\prime}, O \wedge 1-\bar{t} \neq 132^{\circ} 20^{\prime} ; \dot{c}: \bar{b}: \breve{a}=1.0977$. $1 \cdot 1511: 1$, Miller. Cleavage : $i-2$ imperfect, $i-\check{\imath}$ and $i-\bar{\imath}$ in traces.
H. $=3 \cdot 5-4$. G. $=3 \cdot 1-3 \cdot 3$. Lustre vitreous-subadamantine and subresinous. Color pale leek-green or liver-brown. Streak white. Subtransparent-translucent. Fracture aneven.

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Obs.-Found at Schwarzenberg in Saxony ; at Nertschinsk, Siberia ; Dernbach in Nassau; in the Cornish mines; at the Minas Geraes, in Brazil; in Popayan; at the gold mines of Victoria in Aui tralia. Occurs in minute crystals and druses, near Edenville, N. Y.; in Cabarras Co., N. C.

## WAVELLITE.

Orthorhombic. $I \wedge I=126^{\circ} 25^{\prime}, O \wedge 1-\bar{\imath}=143^{\circ} 23^{\prime} ; \dot{c}: \bar{b}: \breve{a}=0 \cdot 7431$ $: 1 \cdot 4943: 1$. Cleavage: $I$ rather perfect; also brachydia-
686 gonal. Usually in hemispherical or globular concretions,
 having a radiated structure.
$\mathrm{H} .=3 \cdot 25-4 . \quad \mathrm{G}_{.}=2 \cdot 316-2 \cdot 337$. Lustre vitreous, inclining to pearly and resinons. Color white, passing into yellow, green, gray, brown, and black. Streak white. Translucent.

Comp. $-\mathrm{Al}_{3} \mathrm{P}_{4} \mathrm{O}_{19}, 12 \mathrm{aq}=2 \mathrm{AlP}_{2} \mathrm{O}_{8}+\mathrm{H}_{6} \mathrm{AlO}_{8}+9 \varepsilon q=$ Phosphorus pentoxide $35 \cdot 16$, alumina $38 \cdot 10$, water $26 \cdot 74=100$; 1 to 2 p. c. fluorine is often present, replacing the oxygen.
Pyr., etc.-In the closed tube gives off much water, the last portions of which react acid and color Brazil-wood paper yellow (fluorine), and also etch the tube. B B. in the forceps swells up and splits frequently into fine acicular particles, which are infusible, but color the flame pale green; moistened with sulphuric acid the green becomes more intense. Gives a blue with cobalt solution. Some varieties react for iron and manganese with the fluxes. Heated with sulphuric acid gives off fumes of fluohydric acid, which etch glass. Soluble in hydrochloric acid, and also in caustic potash.

Diff.-Distinguished from the zeolites and from gibbsite by its giving a phosphorus reaction; it dissolves in acid without gelatinization.
Obs.-Found near Barnstaple, Devonshire ; at Clonmel and Cork, Ireland; in the Shiant Isles of Scotland; at Zbirow in Bohemia; Zajecov in Bohemia; at Frankenberg and Langenstriegis, Saxony; Diensberg, near Giessen, Hesse Darmstadt; in a manganese mine in Weinbach, near Weilburg, in Nassau ; at Villa Rica, Minas Geraes, Brazil. In the United States, at the slate quarries of York Co., Pa.; at Washington mine, Davidson Co., N. C.; at White Horse Station, Chester Co., Pa; Magnet Cove, Ark.
ZePIAROVICHITE. - Near wavellite. Composition $\mathrm{AlP}_{2} \mathrm{O}_{8}+6 \mathrm{aq}$ (or 5aq, Ramm.). Compact. Color greenish to grayish. Occurs in sandstone at Trenic, Bohemia.
Ceruleolactite. - Crypto-crystalline. Color milk-white to light blue. Composition (Petersen) $\mathrm{Hl}_{3} \mathrm{P}_{4} \mathrm{O}_{19}+10 \mathrm{aq}$. Katzenellnbogen. Nassau. Also Chester Co., Penn. (Genth, who regards the copper, 4 p. c., as belonging to the mineral.)

## PHARMACOSIDERITE. Würfelerz, Germ.

Isometric ; tetrahedral. Crystals modified cubes and tetrahedrons. Cleavage: cubic, imperfect. $O$ sometimes striated parallel to its edge of intersection with plane 1 ; planes often curved. Rarely granular.
$\mathrm{H} .=2 \cdot 5$. G. $=2 \cdot 9-3$. Lustre adamantine to greasy, not very distinct Color olive-green, passing into yellowish-brown, bordering sometimes uporn hyacinth-red and blackish-brown; also passing into grass-green, emeraldgreen, and honey-yellow. Streak green-brown, yellow, pale. Subtrans-parent-subtranslucent. Rather sectile. Pyroelectric.

[^46]Named from фа́ $\rho \mu \alpha \kappa о \nu$, poison (in allusion to the arsenic present), and $\sigma i \delta \eta \rho o s, i r o n$. Würfor erz, of the Germans, means cube-ore.

RHAGITE (Weisbach). -Composition $\mathrm{Bi}_{10} \mathrm{As}_{4} \mathrm{O}_{25}+9 \mathrm{aq}=2 \mathrm{BiAsO}_{4}+3 \mathrm{H}_{3} \mathrm{BiO}_{3}=$ Arsenic pentoxide $15 \cdot 6$, bismuth oxide $78 \cdot 9$, water $5 \cdot 5=100$. Spherical crystalline aggregates. Color bright green. Schneeberg, Saxony.

PLUMBOGUMMITE.-Composition uncertain. Contains essentially alumina, lead, water, and phosphorus pentoxide. Huelgoet; Cumberland; Mine la Motte, Mo.

## CHILDRENITE.*

Orthorhombic. $I \wedge I=111^{\circ} 54^{\prime}, O \wedge 1-\bar{\imath}=136^{\circ} 26^{\prime} ; \dot{c}: \bar{b}: \breve{a}=0.9518$ $1 \cdot 4798: 1$. Plane $O$ sometimes wanting, and the form a double sixsided pyramid, made up of the planes $1,2-\zeta$, with $i-\imath$ small. Cleavage: $i-\imath$, imperfect.


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$\mathrm{H} .=4 \cdot 5-5$. G. $=3 \cdot 18-3 \cdot 24$. Lustre vitreous, inclining to resinous. Color yellowish-white and pale yellowish-brown, also brownish-black. Streak white, yellowish. Translucent. Fracture uneven.

Comp.-Formula somewhat uncertain. Analysis: Rammelsberg, $\mathrm{P}_{2} \mathrm{O}_{5} 28.92, \mathrm{AlO}_{3} 14 \cdot 44$, $\mathrm{FeO} 30 \cdot 68, \mathrm{MnO} 9.07, \mathrm{MgO} 0 \cdot 14, \mathrm{H}_{2} \mathrm{O} \quad 16.98=100 \cdot 23$.

Pyr., etc.-In the closed tube gives off neutral water. B.B. swells up into ramifications, and fuses on the edges to a black mass, coloring the flame pale green. Heated on charcoal turns black and becomes magnetic. With soda gives a reaction for manganese. With borax and salt of phosphorus reacts for iron and manganese. Soluble in hydrochloric acid.

Obs.-Occurs near Tavistock; also at Wheal Crebor, in Devonshire; on slate at Crinnis mine in Cornwall. Hebron, Me. (f. 688.).

Reniform, stalactitic or incrusting. Cleavage none.
$\mathrm{H} .=6$. G. $=2 \cdot 6-2 \cdot 83$. Lustre somewhat waxy, feeble. Color sky-blue, bluish-green to apple-green. Streak white or greenish. Feebly subtrans-lucent-opaque. Fracture small conchoidal.

Comp.-Hydrous aluminum phosphate, perhaps $\mathrm{Al}_{2} \mathrm{P}_{2} \mathrm{O}_{11}+5 \mathrm{aq}=$ Phosphorus pentoxide $32 \cdot 6$, alumina $46 \cdot 9$, water $20 \cdot 5=100$
Pyr., etc.-In the closed tube decrepitates, yields water, and turns brown or black. B.B. in the forceps becomes brown and assumes a glassy appearance, but does not fuse; colors the flame green; moistened with hydrochlorio acid the color is at first blue (copper chloride). With the sodium test gives phosphuretted hydrogen. With borax and salt of phosphorus gives beads in O.F. which are yellowish-green while hot, and pure green on cooling. With salt of phosphorus and tin on charcoal gives an opaque red bead (copper). Soluble in hydrochlorio acid.

Obs.-Occurs in clay slate in a mountainous district in Persia, not far from Nichabour. According to Agaphi, the only naturalist who has visited the locality, turquois occurs only in veins, which traverse the mountain in all directions. An impure variety is found in Silesia,
and at Oelsnitz in Saxony. W. P. Blake refers here to a hard yellowish- to bluish-green stone (which he identifies with the chalchihuitl of the Mexicans) from the mountains Los Cerillas, 20 m . S. E. of Sauta Fé. A pale green turquois occurs in the Columbus district, Nevada.

Turquois receives a good polish, and is highly esteemed as a gem. The Persian king is said to retain for his own use all the larger and finely tinted specimens.

Peganite.-Composition $\mathrm{Al}_{2} \mathrm{P}_{2} \mathrm{O}_{11}+6 \mathrm{aq}=$ Phosphorus pentoxide $31 \cdot 1$, alumina $31 \cdot 1$, water $23 \cdot 7=100$. Striegis, Saxony.
DUFRENITE.-Composition $\mathrm{Fe}_{2} \mathrm{P}_{2} \mathrm{O}_{11}+3 \mathrm{aq}\left(\mathrm{FeP}_{2} \mathrm{O}_{11}+\mathrm{H}_{6} \mathrm{FeO}_{6}\right)=$ Phosphorus pentoxide 27.5 , iron sesquioxide 62.0 , water $10.5=100$. Anglar, Dept. of Haute Vieune; Hirschberg, Westphalia ; Allentown, N. J. In deposits of nodules 1 to 6 in. thick, in Rockbridge Co., Va Andiewsite.-In globular forms, having a radiated structure. $H .=4$. G. $=3.475$. Color dark green. Analysis, Flight, $\mathrm{P}_{2} \mathrm{O}_{5} 26 \cdot 09, \mathrm{FeO}_{3} 44 \cdot 64, \mathrm{AlO}_{3} 0.92, \mathrm{CuO} 10 \cdot 86, \mathrm{FeO} 7 \cdot 11$, $\mathrm{MnO} 0.60, \mathrm{CaO} 0.09, \mathrm{SiO}_{2} 0.49, \mathrm{H}_{2} \mathrm{O} 8.79=99.59$. In a tin lode, West Phenix mine, near Liskeard, Cornwall.

Chalcosiderite.-In bright green crystals (triclinic) on Andrewsite (see above). H. = $4 \cdot 5$. G. $=3 \cdot 108$. Analysis, Flight, $\mathrm{P}_{2} \mathrm{O}_{5} 29 \cdot 93, \mathrm{As}_{2} \mathrm{O}_{5} 0 \cdot 61, \mathrm{FeO}_{3} 42 \cdot 81, \mathrm{AlO}_{3} 4 \cdot 45 . \mathrm{CuO} 8 \cdot 14$, $\mathrm{H}_{2} \mathrm{O} 15 \cdot 00, \mathrm{UO}_{3} \mathrm{tr} .=100 \cdot 94$. Also as a coating on dufrenite. Cornwall. Sayn, Westphalia.

Henwoodite.-In globular forms, with a radiated structure. H. $=4-4.5$. G. $=2.67$. Color turquois-blue to bluish-green. B. B. infusible. Analysis, $\mathrm{P}_{2} \mathrm{O}_{5} 48.94$, $\mathrm{AlO}_{3} 18.24$. $\mathrm{FeO}_{3} 2 \cdot 74, \mathrm{CuO} 7 \cdot 10, \mathrm{CaO} 0 \cdot 54, \mathrm{H}_{2} \mathrm{O} 17 \cdot 10, \mathrm{SiO}_{2} 1 \cdot 37$, loss $3 \cdot 97=100$. Occurs on limonite at the West Phenix mine, Cornwall (Collins, Min. Mag., 1, p. 11).

Cacoxenite. - Supposed to be an iron wavellite. Composition $\mathrm{Fe}_{2} \mathrm{P}_{2} \mathrm{O}_{11}+12 \mathrm{aq}$. In radiated tufts. Color yellow. Hrbeck mine, Bohemia.
Arseniosiderite.--Analysis by Church, $\mathrm{As}_{2} \mathrm{O}_{6} 39 \cdot 86, \mathrm{FeO}_{3} 35 \cdot \%$, $\mathrm{CaO} 15.53, \mathrm{MgO} 0.18$, $\mathrm{K}_{2} \mathrm{O} 0 \cdot 47, \mathrm{H}_{2} \mathrm{O} 7 \cdot 87=9966$. Formula (Ramm.) $2 \mathrm{Ca}_{3} \mathrm{As}_{2} \mathrm{O}_{8}+\mathrm{FeAs}_{2} \mathrm{O}_{8}+3 \mathrm{H}_{6} \mathrm{FeO}_{6}$. Romanêche.
Atelestite.-Essentially a bismuth arsenate. In minute yellow crystals at Schneeberg.

## torbernite. Chalcolite. Kupfer-Uranit, Gcrm.

Tetragonal. $O \wedge 1-\bar{\imath}=134^{\circ} 8^{\prime} ; \dot{c}=1 \cdot 03069$. Forms square tables, with often replaced edges ; rarely suboctahedral. Cleav-

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Cornwall. age: basal highly perfect, micaceous. Unknown massive or earthy.
H. $=2-2 \cdot 5 . \quad$ G. $=3 \cdot 4-3 \cdot 6$. Lustre of $O$ pearly, of other faces subadamantine. Color emerald- and grass-green, and sometimes leek-, apple-, and sis-kin-green. Streak somewhat paler than the color, Transparent-subtranslucent. Fracture not observable. Sectile. Laminæ brittle and not flexible. Optically uniaxial; double refraction negative.

[^47]
## AUTUNITE.* Uranit; Kalk-Uranglimmer, Kalk-Uranit, Germ.

Orthorhombic; but form very nearly square, and crystals resembling closely those of torbernite. Cleavage: basal eminent, as in torbernite.
$\mathrm{H} .=2-2.5 . \quad \mathrm{G} .=3 \cdot 05-3 \cdot 19$. Lustre of $O$ pearly ; elsewhere subadamantine. Color citron- to sulphur-yellow. Streak yellowish. Translucent. Optically biaxial, DesCl.

Coinp.-Q. ratio for $\mathrm{R}: \mathrm{U}: \mathrm{P}: \mathrm{H}=1: 6: 5: 10$. Formula $\mathrm{CaU}_{2} \mathrm{P}_{2} \mathrm{O}_{12}+10$ aq, which may he written $2\left(\mathrm{UO}_{2}\right)_{3} \mathrm{P}_{2} \mathrm{O}_{8}+\mathrm{Ca}_{3} \mathrm{P}_{2} \mathrm{O}_{8}+30$ aq. The formula requires: Phosphorus pentoxide $14 \cdot 9$, uranium trioxide $\left(\mathrm{UO}_{3}\right) 60 \cdot 4$, lime $5 \cdot 9$, water $18 \cdot 8=100$.

Pyr., etc.-Same as for torbernite, but no reaction for copper.
Obs.-Occurs at Johanngeorgenstadt; at Lake Onega, Wolf Island, Russia; near Limoges; near Autun; formerly at South Basset, Wheal Edwards, and near St. Day, England. Occurs sparingly at Middletown, Ct. ; also in minute crystals at Chesterfield, Mass. ; at Acworth, N. H.

Trögerite.-Composition $\mathrm{U}_{3} \mathrm{As}_{2} \mathrm{O}_{14}+12 \mathrm{aq}=\left(\mathrm{UO}_{2}\right)_{3} \mathrm{As}_{2} \mathrm{O}_{8}+12 \mathrm{aq}$. This requires: Arsenic pentoxide $17 \cdot 6$, uranium trioxide 65.9 , water $16 \cdot 5=100$. Monoclinic. In thin tabular crystals of a lemon-yellow color. Schneeberg, Saxony.

WALPURGITE.-Composition $\mathrm{Bi}_{1} \mathrm{O}_{3} \mathrm{As}_{4} \mathrm{O}_{34}+12 \mathrm{aq}=\left(\mathrm{UO}_{2}\right)_{3} \mathrm{As}_{2} \mathrm{O}_{8}+2 \mathrm{BiAsO}_{4}+8 \mathrm{H}_{3} \mathrm{BiO}_{3}$. This requires: Arsenic pentoxide $11 \cdot 9$, bismuth oxide $60 \cdot 0$, uranium trioxide $22 \cdot 4$, water $5 \cdot 7=100$. Monoclinic. In thin scaly crystals. Color wax-yellow. Schneeberg, Saxony.

Uranospinite. - An arsenic autunite. Composition $\mathrm{CaU}_{2} \mathrm{\Lambda s}_{2} \mathrm{O}_{12}+8 \mathrm{aq}=\mathfrak{2}\left(\mathrm{UO}_{2}\right)_{2} \mathrm{As}_{2} \mathrm{O}_{8}+$ $\mathrm{Ca}_{3} \mathrm{As}_{2} \mathrm{O}_{8}+24 \mathrm{aq}=$ Arsenic pentoxide $22 \cdot 9$, uranium trioxide $57 \cdot 2$, lime $5 \cdot 6$, water $14 \cdot 3=100$. Color green. Schneeberg, Saxony. Uranospherite. Color yellow. Analysis, Winkler : $\mathrm{U} \mathrm{O}_{3} 50.88, \mathrm{Bi}_{2} \mathrm{O}_{3} 44.34, \mathrm{H}_{2} \mathrm{O} 4.75$. Schneeberg.

Zeunerite.-According to Winkler, an arsenic chalcolite, with which it is isomorphous. Composition $\mathrm{CuU}_{2} \mathrm{As}_{2} \mathrm{O}_{12}+8 \mathrm{aq}=2\left(\mathrm{UO}_{2}\right)_{3} \mathrm{As}_{2} \mathrm{O}_{8}+\mathrm{Cu}_{8} \mathrm{As}_{2} \mathrm{O}_{8}+24 \mathrm{aq}=$ Arsenic pentoxide $22 \cdot 3$, uranium trioxide 56.0 , copper oxide 7.7 , water $14 \cdot 0=100$. Color bright green. Schneeberg, Zinnwald, Saxony; Cornwall.

Prtricite.-Iron-sinter. Composition uncertain. contains $\mathrm{As}_{2} \mathrm{O}_{5}, \mathrm{FeO}_{3}, \mathrm{SO}_{3}, \mathrm{H}_{2} \mathrm{O}$. DiADOCHITE is similar, but contains $\mathrm{P}_{2} \mathrm{O}_{5}$ instead of $\mathrm{As}_{2} \mathrm{O}_{5}$.

## Hydrous Antimonates.

Bindheimite (Bleinière).-Amorphous, reniform, or spheroidal; also earthy or incrusting. H. $=$ 4. G. $=4 \cdot 60-476$. Color white, gray, brownish, yellowish. Composition uncertain; analysis by Hermann: $\mathrm{Sb}_{2} \mathrm{O}_{5} 31 \cdot 71, \mathrm{PbO} 61 \cdot 83, \mathrm{H}_{2} \mathrm{O} 6 \cdot 46=100$. Results from the decomposition of other antimonial ores. From Nertschinsk in Siberia; Horhausen; near Endellion in Cornwall, with jamesonite, from which it is derived.

## Nitrates.

The nitrates are all soluble, and hence are rarely met with in nature. They irclude:
Nitre, potassium nitrate $\left(\mathrm{KNO}_{3}\right)$. Found generally in crusts on the surface of the soil, on walls, rocks, etc. Also found in numerous caves in the Mississippi Valley.

Soda Nitre, sodium nitrate $\left(\mathrm{NaNO}_{3}\right)$. Tarapaca, Chili.
Nitrocalcite, calcium nitrate $\left(\mathrm{CaN}_{2} \mathrm{O}_{6}\right)$. Occurs in silky efflorescences in linestone eaverns.

Nitromagnesite, magnesium nitrate $\left(\mathrm{MgN}_{2} \mathrm{O}_{6}\right)$. From limestone caves Nitroalauberite, nitro-sulphate of sodium. Desert of Atacama, Chili.

## 4. BORATES.

## SASSOLITE.

Triclinic. $I \wedge I^{\prime}==118^{\circ} 30^{\prime}, O \wedge I=95^{\circ} 3^{\prime}, O \wedge I^{\prime}=80^{\circ}$ ज小' $\mathbf{b}^{\prime} \& \mathbb{M}$. Twins: composition-face $O$. Cleavage: basal very perfect. Libually in sinall scales, apparently six-sided tables, and also in stalactiti\% forms, composed of small scales.
$\mathrm{H} .=1$. G. $=1 \cdot 48$. Lustre pearly. Color white, except when tinged yellow by sulphur; sometimes gray. Feel smooth and unctuous. Taste acidulous, and slightly saline and bitter.

Comp. $-\mathrm{H}_{6} \mathrm{~B}_{2} \mathrm{O}_{6}=$ Boron trioxide $\left(\mathrm{B}_{2} \mathrm{O}_{3}\right) 56 \cdot 46$, water $43 \cdot 54=100$. The rantive stalactitio salt contains, mechanically mixed, various impurities, as sulphate of magatsium and iron, sulphate of calcium, silica, etc.

Pyr., etc.-In the closed tube gives water. B. B. on platinum wire fuses to a clear glass and tinges the flame yellowish-green. Soluble in water and alcohol.

Obs.-First detected in nature by Höfer in the waters of the Tuscan lagoons of Monte Rotondo and Castelnuovo, and afterward in the solid state at Sasso by Mascagni. The hot vapors of the lagoons consist largely of it. Exists also in other natural waters, as at Wiesbaden; Aachen; Krankenheil near Fölz; Clear Lake in Lake Co., California; and it has been detected in the waters of the ocean. Occurs also abundantly in the crater of Vulcano, one of the Lipari islands, forming a layer on sulphur and about the fumaroles, where it was discovered by Dr. Holland in 1813.

## SUSSEXITE (Brush).

In fibrous seams or veins.
H. $=3$. G. $=3 \cdot 42$. Lustre silky to pearly. Color white, with a tinge of pink or yellow. Translucent.

Comp. $-\mathrm{R}_{2} \mathrm{~B}_{2} \mathrm{O}_{5}+$ aq, with $\mathrm{R}=\mathrm{Mn}: \mathrm{Mg}=4: 3=$ Boron trioxide $34 \cdot 3$, manganese protoxide $39 \cdot 9$, magnesia $16 \cdot 9$, water $8 \cdot 9=100$.

Pyr., etc. - In the closed tube darkens in color and yields neutral water. If turmeric paper is moistened with this water and then with dilute hydrochloric acid it assumes a red color (boron). Fuses in the flame of a candle, and B.B. in O.F. vields a black crystalline mass coloring the flame intensely yellowish-green. Reacts for manganese with the fluxes. Soluble in hydrochloric acid.

Obs.-Found on Mine Hill, Franklin Furnace, Sussex Co., N. J.; associated with franklinite. zincite, willemite, and other manganese and zinc minerals.

Szaibelyite.-A hydrous magnesium borate, $\mathrm{Mg}_{6} \mathrm{~B}_{4} \mathrm{O}_{11}+3 \mathrm{aq}$ (or $\frac{3}{2} \mathrm{aq}$ ). Occurs in acicular cervstals. Color white. Hungary.
l.udwigite (Tschermak). -Finely fibrous masses. H. $=5$. G. $=3 \cdot 907-4 \cdot 016$. Color black ishegreen to black. Composition $\mathrm{R}_{4} \mp \mathrm{FB}_{2} \mathrm{O}_{10}$, with $\mathrm{R}=\mathrm{Fe}: \mathrm{Mg}=1: 5$, or $1: 3$. For the latter the formula requires: Boron trioxide $16 \cdot 6$, iron sesquioxide $37 \cdot 9$, iron protoxide $17 \cdot 1$, magnesia $28 \cdot 4$. Occurs in a crystalline limestone with magnetite at Morawicza in the Banat. also altered to limonite.

## BORACITE.*

Isometric; tetrahedral. Cleavage: octahedral, in traces. Cubic faces sometimes striated parallel to alternate pairs of edges, as in pyrite.
$\mathrm{H} .=7$, in crystals ; 4.5 , massive. G. $=2 \cdot 974$, Haidinger. Lustre vitroous, inclining to adamantine. Color white, inclining to gray, yellow, and green. Streak white. Sub-transparent-translucent. Fracture conchoidal, uneven. Pyroelectric, and polar along the four octahedral axes.

Comp. $-\mathrm{Mg}_{7} \mathrm{~B}_{16} \mathrm{Cl}_{2} \mathrm{O}_{30}=2 \mathrm{Mg}_{3} \mathrm{~B}_{8} \mathrm{O}_{15}+\mathrm{MgCl}_{2}=$ Boron trioxide $62 \cdot 57$, magnesia $31 \cdot 28$, chlorine $7 \cdot 93=101 \cdot 78$.

Pyr., etc.-The massive variety gives water in the closed tube. B.B. both varieties fuse at 2 with intumescence to a white crys-
 talline pearl, coloring the flame green; heated after moistening with cobalt solution assumes a deep pink color. Mixed with copper oxide and heated on charcoal colors the flame deep azure-blue (copper chloride). Soluble in hydrochloric acid. Alters very slowly on exposure, owing to the magnesium chloride present, which takes up water.

Obs.-Observed in beds of anhydrite, gypsum, or salt. In crystals at Kalkberg and Schildstein in Lüneberg, Hanover ; at Segeberg, near Kiel, in Holstein ; at Luneville, La Meurthe, France ; massive and crystallized ai Stassfurt, Prussia.

BORAX. Tinkal of India.
Monoclinic. $C=73^{\circ} 25^{\prime}, I \wedge I=87^{\circ}, O \wedge 2-\grave{\imath}=132^{\circ} 49^{\prime} ; \dot{c}: b: a=$ $0 \cdot 4906: 0.9095: 1$. Cleavage : $i-i$ perfect; $I$ less so; $i-\grave{\imath}$ in traces.
$\mathrm{H} .=2-2 \%$. G. $=1.716$. Lustre vitreons-resinous; sometimes earthy. Color white; sometimes grayish, bluish, or greenish. Streak white. Translucent-opaque. Fracture conchoidal. Rather brittle. Taste sweet-ish-alkaline, feeble.

Comp. $-\mathrm{Na}_{2} \mathrm{~B}_{4} \mathrm{O}_{7}+10 \mathrm{aq}=2\left(\mathrm{NaBO}_{2}+\mathrm{HBO}_{2}\right)+9 \mathrm{aq}=$ Boron trioxide $36 \cdot 6$, soda 16.2 , water 47.2.

Pyr., eto.-B.B. puffs up, and afterwards fuses to a transparent globule, called the glass of borax. Soluble in water, yielding a faintly alkaline solution. Boiling water dissolves double its weight of this salt.

Obs.-Borax was originally brought from a salt lake in Thibet. It is announced by Dr. J. A. Veatch as existing in the waters of the sea along the California coast, and in those of many of the mineral springs of California. Occurs in the mud of Borax Lake, near Clear Lake, Cal. Also found in Peru; at Halberstadt in Transylvania; in Ceylon. It occurs in solution in the mineral springs of Chambly, St. Ours, etc., Canada East. The waters of Borax Lake, California, contain, according to G. E. Moore, 535.08 grains of crystallized borax to the gallon.

ULEXITE. Boronatrocalcite. Natronborocalcite.
In rounded masses, loose in texture, consisting of fine fibres, which are acicular or capillary crystals.
$H .=1$. G. $=165$, N. Scotia, How. Lustre silky within. Color white. Tasteless.

Comp. $-\mathrm{NaCaB} \mathrm{O}_{0}+5 \mathrm{aq}=$ Boron trioxide $49 \cdot \%$, lime $15 \cdot 9$, soda $8 \cdot 8$, water $25 \cdot 6=100$.
Pyr., etc.-Yields water. B.B. fuses at 1 with intumescence to a clear blebby glass, cclor
ing the flame deep yellow. Moistened with sulphuric acid the color of the flan e is momentarily changed to deep green. Not soluble in cold water, and but little so in hot ; the solation alkaline in its reactions.

Obs.-Occurs in the dry plains of Iquique, Southern Peru; in the province of Tarapaca (where it is called tiza), in whitish rounded masses, from a hazelnut to a potato in size, which consist of interwoven fibres of the ulexite, with pickeringite, glauberite, halite. gypsum, and other impurities; on the West Africa coast; in Nova Scotia, at Windsor, Brookville, and Newport (H. How), filling narrow cavities, or constituting distinct nodules or mammillated masses imbedded in white gypsum, and associated at Windsor with glauber salt, the lustre internally silky and the color very white; in Nevada, in the salt marsh of the Columbus Mining District, forming layers 2-5 in. thick alternating with layers of salt, and in balls 3-4 in. through in the salt.

Becrulite. (Borocalcite). - An incrustation at the Tuscany lagoons. Composition $\mathrm{CaB}_{4} \mathrm{O}$, +4 aq . Also similar from South America. Larderellite, Lagonite, rare borates from the Tuscan lagoons.
Priceite (Silliman).-Compact, chalky. Color milk-white. Composition $\mathrm{Ca}_{3} \mathrm{~B}_{8} \mathrm{O}_{15}+6$ aq. This requires : Boron trioxide $49 \cdot 8$, lime $29 \cdot 9$, water $20 \cdot 3=100$. Occurs in layers between a bed of slate above and one of steatite below. Near Chetko, Curry Co., Oregon.

Howlite, Silicoborocalcitc.-A hydrous calcium borate (like bechilite), with one-sixth of a silicate analogous to danburite. Near Brookville, and elsewhere in Hants Co., Nova Scotia, in nodules imbedded in anhydrite or gypsum ; these nodules sometimes made up of pearly crystalline scales. Winkwortirite. In imbedded crystalline nodules from Winkworth, N.S. In composition between selenite and howlite; a mixture' (?).

Cryptomorpirite.-Near ulexite in composition. In microscopic rhombic tables. Nova Scotia.

Lüneburgite.-A phospho-borate of magnesium. Flattened masses in gypsiferous marl at Lüneburg.

## WARWICKITE.

Monoclinic. $I \wedge I=91^{\circ} 20^{\prime}$, DesCl. Usual in rhombic prisms with obtuse edges truncated, and the acute berelled, summits generally rounded; surfaces of larger crystals not polished. Cleavage: macrodiagonal perfect, affording a surface with vertical striæ and traces of oblique cross cleavage.
H. $=3-4$. G. $=3 \cdot 19-3 \cdot i 3$. Lustre of cleavage surface submetallic-pearly to subvitreous; often nearly dull. Color dark hair-brown to dull black, sometimes a copper-red tinge on cleavage surface. Streak bluish-black. Fracture meven. Brittle.

Comp.-Essentially a borotitanate of magnesium and iron. Analysis, Smith, $\mathrm{B}_{2} \mathrm{O}_{3} 27 \cdot 80$, $\mathrm{TiO}_{2} 23 \cdot 82, \mathrm{FeO}_{3} 7 \cdot 02, \mathrm{MgO} 36 \cdot 80, \mathrm{SiO}_{2} 1 \cdot 00, \mathrm{AlO}_{3} 2 \cdot 21=98 \cdot 65$.
Pyr., etc.-Yields water. B.B. infusible, but becomes lighter in water; moistened with sulphuric acid gives a pale green color to the flame. With salt of phosphorus in O.F. a clear bead, yellow while hot and colorless on cooling; in R.F. on charcoal with tin a violet color (titanium). With soda a slight manganese reaction. Decomposed by sulphuric acid; the product, treated with alcohol and ignited, gives a green flame, and boiled with hydrochloric acid and metallic tin gives on evaporation a violet-colored solution.

Obs.-Occurs in granular limestone $2 \frac{1}{2}$ m. S. W. of Edenville, N. Y., with spinel, chondrodite, serpentine, etc. Crystals usually small and slender; sometimes over 2 in . long avd of in. broad.

## 5. TUNGSTATES MOLYBDATES, CHROMATES.

## WOLFRAMITE.

Monoclinic. $C=89^{\circ} 22^{\prime}, I \wedge I=100^{\circ} 37^{\prime}, i-i \wedge-\frac{1}{2}-i=118^{\circ} 6^{\prime}, i-i \wedge+\frac{1}{2}-i$ $=117^{\circ} 6^{\prime}, 1-\grave{\imath} \wedge 1-\grave{\imath}=98^{\circ} 6^{\prime}$, DesCloizeanx. Cleavage: $i-\grave{\imath}$ perfect, $i-j$ imperfect. Twins: planes of twinning $i-i$ (f. 692), $\frac{2}{3}-i$, and rarely $\frac{1}{8}-i$. Also irregular lamellar; coarse divergent columnar; massive granular, the particles strongly coherent.

$\mathrm{H} .=5-5 \cdot 5 . \quad \mathrm{G} .=7 \cdot 1-7 \cdot 55 . \quad$ Lustre submetallic. Color dark graysh or brownish-black. Streak dark reddish-brown to black. Opaque. Sometimes weak magnetic.

Var.-The most important varieties depend on the proportions of the iron and manganese. Those rich in manganese have G. $=7 \cdot 19-7 \cdot 54$, but generally below 7.25, and the streak is mostly black. Those rich in iron have G. $=7 \cdot 2-7 \cdot 54$, and a dark reddish-brown streak, and they are sometimes feebly attractable by the magnet.

Comp.-( $\mathrm{Fe}, \mathrm{Mn}) \mathrm{WO}_{1}, \mathrm{Fe}: \mathrm{Mn}=2: 3$, mostly; also $4: 1$ and 2:1, $3: 1,5: 1$, etc. The ratio 2:3 corresponds to : Tungsten trioxide $76 \cdot 47$, iron protoxide $9 \cdot 49$, manganese protoxide $14 \cdot 04=100$.

Pyr., etc.-B.B. fuses easily (F. $=2 \cdot 5-3$ ) to a globule, which has a crystalline surface and is magnetic. With salt of phosphorus gives a clear reddish-yellow glass while hot, which is paler on cooling; in R.F. becomes dark red; on charcoal with tin, if not too saturated, the bead assumes on cooling a green color, which continued treatment in R.F. changes to reddishyellow. With soda and nitre on platinum foil fuses to a bluish-green manganate. Decomposed by aqua regia with separation of tungsten trioxide as a yellow powder, which when treated B.B. reacts as under tungstite (p.284). Wolfram is sufficiently decomposed by concentrated sulphuric acid, or even hydrochloric acid, to give a colorless solution, which, treated with metallic zinc, becomes intensely blue, but soon bleaches on dilution.

Diff.-Characterized by its high specific gravity and pyrognostics.
Obs.-Wolfram is often associated with tin ores; also in quartz, with native bismuth, scheelite, pyrite, galenite, blende, etc.; and in trachyte, as at Felsöbanya, in Hungary. It occurs at Schlackenwald ; Schneeberg ; Freiberg ; Ehrenfriedersdorf ; Zinnwald, and Nertschinsk; at Chanteloup, near Limoges, and at Meymac, Corrèze, in France ; near Redruth and elsewhere in Cornwall ; in Cumberland. Also in S. America, at Oruro in Bolivia.

In the U. States, occurs at Lane's mine, Monroe, Conn.; at Trumbull, Conn. ; on Camdage farm, near Blue Hill Bay, Me.; at the Flowe mine, Mecklenburg Co., N. C.; in Missouri, near Mine la Motte, and in St. Francis Co.; at Mammoth mining district, Nevada.

Hübnerite. ${ }^{*}$ - A manganese wolframite, $\mathrm{MnWO}_{4}=$ Tungsten trioxide 769 , manganese protoxide $23 \cdot 1=100$. Mammoth dist., Nevada.

Megabasite.-A manganese tungstate, with a little iron. Schlackenwald.

## SCHEELITE.

Tetragonal ; hemihedral. $O \wedge 1-i=123^{\circ} 3^{\prime} ; \dot{c}=1 \cdot 5369$. Cleavage : 1 most distinct, $1-i$ interrupted, $O$ traces. Twins:


Schlackenwald. twinning-plane $I$; also $i-i$. Crystals usually octahedral in form. Also reniform with columnar structure; and massive granular.
H. $=4 \cdot 5-5$. G. $=5 \cdot 9-6 \cdot 076$. Lustre vitreous, inclining to adamantine. Color white, yellowish-white, pale yellow, brownish, greenish, reddish; sometimes almost orange-yellow. Streak white. Transparent -translucent. Fracture uneven. Brittle.

> Comp.-CaWO ${ }_{4}=$ Tungsten trioxide $80 \cdot 6$, lime $19 \cdot 4=100$. A variety from Coquimbo, Chili, contained $6 \cdot 2$ p. c. vanadium pentoxide; another from Traversella contained didymium.
> Pyr., etc.-B.B. in the forceps fuses at 5 to a semi-transparent glass. Soluble with borax to a transparent glass, which afterward becomes opaque and crystalline. With salt of phosphorus forms a glass, colorless in outer flame, in inner green when hot and fine blue cold, varieties containing iron require to be treated on charcoal with tin before the blue color appears. In hydro chloric or nitric acid decomposed, leaving a yellow powder soluble in ammonia.

Diff.-Remarkable among non-metallic minerals for its high specific gravity.
Obs.-Usually associated with crystalline rocks, and commonly found in connection with tin ore, topaz, fluorite, apatite, molybdenite, wolframite, in quartz. Occurs at Schlackenwald and Zinnwald in Bohemia; in the Riesengebirge; at Caldbeck Fell, near Keswick; Neudorf in the Harz; Ehrenfriedersdorf; Pösing in Hungary; Traversella in Piedmont, etc. Llamuco, near Chuapa in Chili. In the U. S., at Lane's mine, Monroe, and Huntington, Conn.; at Chesterfield, Mass.; in the Mammoth mining district, Nevada; at Bangle mine, in Cabarras Co., N. C.; and Flowe mine, Mecklenburg Co.

Cuproscheelite.-A scheelite containing about 6 p. c. copper oxide. Color bright green. La Paz, Lower California. Llamuco, near Santiago, Chili.

Cuprotungstite.-A copper tungstate, $\mathrm{Cu}_{2} \mathrm{WO}_{5}+$ aq. Amorphous. Color yellowishgreen. With cuproscheelite at the copper mines of Llamuco, Chili.
Stolzite. $-\mathrm{PbWO}_{4}=$ Tungsten trioxide 51, lead oxide $49=100$. Tetragonal. Zinnwald ; Bleiberg; Coquimbo, Chili.

## wUlpenite.* Gelbbleierz, Germ.

Tetragonal. Sometimes hemihedral. $O \wedge 1-i=129^{\circ} 26^{\prime} ; \dot{c}=1.574$.

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Phenixville.

In modified square tables and sometimes very thin octahedrons. Cleavage :

1 very smooth; $O$ and $\frac{1}{8}$ much less distinct. Also granularly massive, coarse or fine, firmly cohesive. Often hemihedral in the octagonal prisms, producing this tables like f. 696, and octahedral forms having the prismatic planes similarly oblique.
H. $=2 \cdot 75-3$. G. $=6 \cdot 03-7 \cdot 01$. Lustre resinous or adamantine. Color wax-yellow, passing into orange-yellow; also siskin- and olive-green, yel-lowish-gray, grayish-white, brown; also orange to bright red. Streak white. Subtransparent-subtranslucent. Fracture subconchoidal. Brittle.

Var.-1. Ordinary. Color yellow. 2. Vanadiferous. Color orange to bright red, a variety occurring at Phenix ville, Pa.

Comp.-PbMiou $=$ Molybdenum trioxide $38 \cdot 5$, lead oxide $61 \cdot 5=100$. Some varieties contain chromium.
Pyr., etc.-B.B. decrepitates and fuses below 2; with borax in O.F. gives a colorless glass, in R.F. it becomes opaque black or dirty green with black flocks. With salt of phosphorus in O.F. gives a yellowish-green glass, which in R.F. becomes dark green. With soda on charcoal yields metallic lead. Decomposed on evaporation with hydrochloric acid, with the formation of lead chloride and molybdic oxide ; on moistening the residue with water and adding metallic zinc, it gives an intense blue color, which does not fade on dilution of the liquid.

Obs.-This species occurs in veins with other ores of lead. Found at Bleiberg, etc., in Carinthia ; at Retzbanya; at Przibram ; Schneeberg and Johanngeorgenstadt; at Moldava; in the Kirghis Steppes in Russia; at Badenweiler in Baden; in the gold sands of Rio Chico in Antioquia, Columbia, S. A.; Wheatley's mine, near Phenixville, Pa.; at the Comstock lode in Nevada. In fine specimens from the Empire mine, Lucin District, Box Elder County, Utah ; at Empire mine, Inyo Co., Cal. ; in the Weaver dist., Arizona.

Eosite (Schrauf ).-In minute tetragonal octahedrons. Color deep-red. Probably a vana-dio-molybdate of lead. Leadhills, Scotland.

Achmematite.-An arsenio-molybdate of lead. Analysis, $\mathrm{As}_{2} \mathrm{O}_{5} 18: 25, \mathrm{MoO}_{3} 5.01, \mathrm{Cl}$ $2 \cdot 15, \mathrm{~Pb} 6 \cdot 28, \mathrm{PbO} 68 \cdot 31=100 \cdot 00$. Compact; structure indistinctly crystalline. H. $=3-4$. G. $=5.965,6.178$ (powder). Color liver-brown, translucent; in minute grains transparent and color yellow. Brittle. Guanaceré, State of Chihuahua, Mexico. (Mallet, J. Ch. Soc., xiii., 1141, New Series.)

## CROCOITE. Crocoisite. Rothbleierz, Germ.

Monoclinic. $C^{\gamma}=77^{\circ} 27^{\prime}, I \wedge I=93^{\circ} 42^{\prime}, O \wedge 1-\grave{\imath}=138^{\circ} 10^{\prime} ; c \dot{c}: b: a$ $=0.95507: 1.0414: 1$, Dauber. Cleavage : $I$ tolerably distinct; $O$ and $i-i$ less so. Surface $I$ streaked longitudinally; the faces mostly smooth and shining. Also imperfectly columnar and granular.
H. $=2 \cdot 5-3$. G. $=5 \cdot 9-6 \cdot 1$. Lustre adamantinevitreous. Color various shades of bright hyacinthred. Streak orange-yellow. Translucent. Sectile.

Comp. $-\mathrm{PbCrO}_{4}=$ Lead oxide $69 \cdot 0$, chromium trioxide $31 \cdot 0=$ 100.

Pyr., etc.-In the closed tube decrepitates, blackens, but rezovers its original color on cooling. B.B. fuses at $1 \cdot 5$, and on charcoal is reduced to metallic lead with deflagration, leaving a residue of chromic oxide, and giving a lead coating. With salt of phosphorus gives an emerald-green bead in both flames. Fused with potassium bisulphate in the platinum spoon forms a dark violet mass, which on solidifying becomes reddish, and when
 cold greenish-white, thus differing from vanadinite, which on similar treatment gives a yellow mass (Plattner).

Obs.-First found at Beresof in Siberia; at Mursinsk and near Nischne Tagilsk in the Ural ; in Brazil; at Retzbanya; Moldawa; on Lazon, one of the Philippines.

PHGENICOCHROITE. Melanochroite.
Orthorhombic (?). Crystals usually tabular, and reticularly interwoven. Cleavage in one direction perfect. Also massive.
$\mathrm{H} .=3-3 \cdot 5$. G. $=5 \cdot 75$. Lustre resinous or adamantine, gliminering. Color between cochineal- and hyacinth-red; becomes lemon-yellow on exposure. Streak brick-red. Subtranslucent-opaque.

Comp. $-\mathrm{Pb}_{3} \mathrm{Cr}_{2} \mathrm{O}_{9}=2 \mathrm{PbCrO}_{4}+\mathrm{PbO}=$ Chromium trioxide $23 \cdot 0$, lead oxide $77 \cdot 0=100$.
Pyr., etc.-B.B. on charcoal fuses readily to a dark mass, which is crystalline when cold. In R.F. on charcoal gives a coating of lead oxide, with globules of lead and a residue of chromic oxide. Gives the reaction of chrome with fluxes.
Obs.-Occurs in limestone at Beresof in the Ural, with crocoite, vauquelinite, pyromorphite, and galenite.

## VAUQUELINITE.

Monoclinic. Crystals usually minute, irregularly aggregated. Also reniform or botryoidal, and granular; amorphous.
$\mathrm{H} .=2 \cdot 5-3$. G $=5 \cdot 5-5 \cdot 78$. Lustre adamantine to resinous, often faint. Color green to brown, apple-green, siskin-green, olive-green, ochre-brown, liver-brown; sometimes pearly black. Streak greenish or brownish. Faintly translucent-opaque. Fracture uneven. Rather brittle.

Comp $-\mathrm{Pb}_{2} \mathrm{CuCr}_{2} \mathrm{O}_{9}=2 \mathrm{RCrO}_{4}+\mathrm{RO} . \quad \mathrm{R}=\mathrm{Pb}: \mathrm{Cu}=2: 1$. The formula requires: Chromium trioxide $27 \cdot 6$, lead oxide $61 \cdot 5$, copper oxide $10 \cdot 9=100$.
Pyr., etc.-B.B. on charcoal slightly intumesces and fuses to a gray submetallic globule, yielding at the same time small globules of metal. With borax or salt of phosphorus affords a green transparent glass in the outer flame, which in the inner after cooling is red to black, according to the amount of mineral in the assay; the red color is more distinct with tin. Partly soluble in nitric acid.

Obs.-Occurs with crocoite at Beresof in Siberia, generally in mammillated or amorphous masses, or thin crusts; also at Pont Gibaud in the Puy de Dome; and with the crocoite of Brazil. In the U. States it has been found at the lead mine near Sing Sing, in green and brownish-green mammillary concretions, and also nearly pulverulent; and at the Pequa lead mine in Lancaster Co., Pa., in minute crystals and radiated aggregations on quartz and galenite, of a siskin- to apple-green color, with cerussite.
Laxmarinite (phosphochromite).-Near vauquelinite, but held to be a pluepho-chromate. Beresof

## 6. SULPHATES.

## Anhynrous Sulphates.

## Barite Group.

BARITE. Barytes. Heavy Spar. Schwerspath, Germ.
Orthorhombic. $I \wedge I=101^{\circ} 40^{\prime}, O \wedge 1-\bar{\imath}=121^{\circ} 50^{\prime} ; \dot{c}: \bar{b}: a \check{c}=1 \cdot 610 \%$

: $1 \cdot 2276: 1 . \quad 0 \wedge 1=115^{\circ} 42^{\prime} ; \frac{1}{2}-\bar{i} \wedge \frac{1}{2}-\bar{i}$, top,$=$ $102^{\circ} 17^{\prime}$; 1-乞^1-乞, top, $=74^{\circ} 36$. Crystals usually tabular, as in figures; sometimes prismatic in the direction of the different axes. Cleavage: basal rather perfect ; $I$ somewhat less so ; $i-\imath$ imperfect. Also in globular forms, fibrous or lamellar, crested ; coarsely laminated, laminæ convergent and often curved ; also granular ; colors sometimes banded, as in stalagmite.
$\mathrm{H} .=2 \cdot 5-3 \cdot 5$. G. $=4 \cdot 3-4 \cdot 72$. Lustre vitreous, inclining to resinous; sometimes pearly. Streak white. Color white; also inclining to yellow, gray, blue, red, or brown, dark brown. Transparent to translucent-opaque. Sometimes fetid, when rubbed. Optic-axial plane brachydiagonal.

Comp.- $\mathrm{BaSO}_{4}=$ Sulphur trioxide $34 \cdot 3$, baryta $65 \cdot 7=100$. Strontium and sometimes calcium replace part of the barium; also silica, clay, bituminous or carbonaceous substances are often present as impurities.
Pyr., etc.-B.B. decrepitates and fuses at 3, coloring the flame yellowish-green; the fused mass reacts alkaline with test paper. On charcoal reduced to a sulphide. With soda gives at first a clear pearl, but on continued blowing yields a hepatic mass, which spreads out and soaks into the coal. If a portion of this mass be removed, placed on a clean silver surface, and moistened, it gives a black spot of silver sulphide. Should the barite contain calcium sulphate, this will not be absorbed by the coal when treated in powder with soda. Insoluble in acids.
Diff.-Distinguishing characters: high specific gravity, higher than celestite or aragonite ; cleavage; insolubility; green coloration of the blowpipe flame.
Obs.-Occurs commonly in connection with beds or veins of metallic ores. as part of the gaugue of the ore. It is met with ir: secondary limestone, sometimes forming distinct veins; and often in crystals along with calcite and celestite. At Dufton, in Westmoreland. Eng
land; in Cornwall, near Liskeard, etc., in Cumberland and Lancashire, in Derbyshire, Staf fordshire, etc.; in Scotland, in Argyleshire, at Strontian. Some of the nost important European localities are at Felsöbanya and Kremnitz, at Freiberg, Marienberg, Clausthal, Przibram, and at Roya and Roure in Auvergne.

In the U. S., in Conn., at Cheshire. In N. York, at Pillar Point; at Scoharie; in St. Lawrence Co.; at Fowler; at Hammond. In Virginia, at Eldridge's gold mine in Buckingham Co.; near Lexington, in Rockbridge Co.; Fauquier Co. In Kentucky, near Paris; in the W. end of I. Royale, L. Superior, and on Spar Id., N. shore. In C'anada, at Landsdown. In fine crystals near Fort Wallace, New Mexico.

The white varieties of barite are ground up and employed as a white paint, either alone or mnixed with white lead.

## CELESTITE.

Orthorhombic. $I \wedge I=104^{\circ} 2^{\prime}\left(103^{\circ} 30^{\prime}-104^{\circ} 30^{\prime}\right), \quad O \wedge 1 \cdot \bar{i}=121^{\circ}$ $19 \frac{1}{2}^{\prime} ; \dot{c}: \bar{b} ; \check{a}=1 \cdot 6432: 1 \cdot 2807: 1$. $O \wedge 1=115^{\circ} 38^{\prime}, O \wedge 1-\check{\varepsilon}=127^{\circ} \check{ }{ }^{\circ} 6^{\prime}$, $1 \wedge 1$, mac., $=112^{\circ} 35^{\prime}, 1 \wedge 1$, brach., $=89^{\circ} 26^{\prime}$. Cleavage: $O$ perfect; $I$ distinct; $i-\imath$ less distinct. Also fibrous and radiated; sometimes globular; occasionally granular.

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L. Erie.
H. $=3-3 \cdot 5 . \quad$ G. $=3 \cdot 92-3 \cdot 975$. Lustre vitreons, sometimes inclining to pearly. Streak white. Color white, often faint bluish, and sometimes reddish. Transparent-subtranslucent. Fracture imperfectly conchoidalnneven. Very brittle. Trichroism sometimes very distinct.

Comp. $-\mathrm{SrSO}_{4}=$ Sulphur trioxide $43 \cdot 6$, strontia $56 \cdot 4=100$. Wittstein finds that the blue color of the celestite of Jena is due to a trace of a phosphate of iron.

Pyr., etc.-B.B. frequently decrepitates, fuses at 3 to a white pearl, coloring the flame strontia-red; the fused mass reacts alkaline. On charcoal fuses, and in R.F. is converted into a difficultly fusible hepatic mass; this treated with hydrochloric acid and alcohol gives an intensely red flame. With soda on charcoal reacts like barite. Insoluble in acids.

Diff.-Does not effervesce with acids like the carbonates; specific gravity lower than that of barite; colors the blowpipe flame red.

Obs.-Celestite is usually associated with limestone or sandstone. Occurs also in beds of gypsum, rock salt, and clay ; and with sulphur in some volcanic regions. Found in Sicily, at Girgenti and elsewhere ; at Bex in Switzerland, and Conil in Spain; at Dornburg, near Jena; in the department of the Garonne, France ; in the Tyrol ; Retzbanya ; in rock salt, at Ischl, Austria. Found in the Trenton limestone about Lake Huron, particu'arly on Strontian Island, and at Kingston in Canada; Chaumont Bay, Scoharie, and Lockport, N. Y. ; also the Rossie lead mine ; at Bell's Mills, Blair Co., Penn.
Named from colestis, celestial, in allusion to the faint slade of blue often presented by the mineral.
Barytocelestite.-Celestite containing barium salphate 26 p c. (Grüner), 20.4 p . c. (Turner). $1-\bar{\imath} \wedge 1-\check{\imath}=74^{\circ} 54 \frac{t^{\prime}}{\iota}, \frac{1}{2}-\bar{\imath} \wedge \frac{1}{2}-\bar{\imath}=100^{\circ} 35^{\prime}$, on crystals from Imfeld in the Binnenthal (Neminar). Drammond I. . Lake Erie; Nörton, Hanover.

## ANHYDRITE.

Orthorhombic. $\quad I \wedge I=100^{\circ} 30^{\prime}, O \wedge 1-\bar{\imath}=127^{\circ} 19^{\prime} ; \dot{c}: \bar{b}: \check{a}=13122$ $: 1-2024: 1$. $1-乞 \wedge \wedge 1-\imath$, top,$=85^{\circ}$. Cleavage: $i-\bar{\imath}$ very per-
$\pi 04$


Stassfurt. fect; $i$ - $\check{\imath}$ also perfect; $O$ somewhat less so. Also fibrous, lamellar, granular, and sometimes impalpable. The lamellar and columnar varieties often curved or contorted.
H. $=3-3.5$. G. $=2 \cdot 899-2.985$. Lustre $: i-乞$ and $i-\bar{\imath}$ somewhat pearly; $O$ vitreous; in massive varieties, vitreous inclining to pearly. Color white, sometimes a grayish, blnish, or reddish tinge ; also brick-red. Streak grayishwhite. Fracture uneven; of finely lamellar and fibrous varieties, splintery. Optic-axial plane parallel to $i-\bar{i}$, or plane of most perfect cleavage; bisectrix normal to $O$; Grailich.
Var.-(a) Crystallized; cleavable in its three rectangular directions. (b) fibrous; either parallel, or radiated, or plumose. (c) Fine granular. (d) Scaly granular. Vulpinite is a scaly granular kin! from Vulpino in Lombardy ; it is cut and polished for ornamental purposes. It does not ordinarily contain more silica than common anhydrite. A kind in contorted concretionary forms is the tripestone (Gekrösstein).
Comp.-CaSO ${ }_{4}=$ Sulphur trioxide $58 \cdot 8$, lime $41 \cdot 2=100$.
Pyr., etc.-B.B. fuses at 3, coloring the flame reddish-yellow, and yielding an enamel-like bead which reacts alkaline. On charcoal in R.F. reduced to a sulphide; with soda does not fuse to a clear globule, and is not absorbed by the coal like barite; it is, however, decomposed, and yields a mass which blackens silver; with fluorite fuses to a clear pearl, which is enamel-white on cooling, and by long blowing swells up and becomes infusible. Soluble in hydrochloric acid.

Diff.-Characterized by its cleavage in three rectangular directions; harder than gypsum ; does not effervesce with acids like the carbonates.

Obs.-Occurs in rocks of various ages, especially in limestone strata, and often the same that contain ordinary gypsum, and also very commonly in beds of rock salt. Occurs near Hall in Tyrol ; at Sulz on the Neckar, in Würtemberg ; Bleiberg in Carinthia; Lüneberg, Hanover; Kapnik in IFungary ; Ischl; Aussee in Styria; Berchtesgaden; Stassfurt, in fine crystals. In the U. States, at Lockport, N. Y. In Nova Scotia.

## ANGLESTTE. Bleivitriol, Germ.

Orthorhombic. $\quad I \wedge I=103^{\circ} 43 \frac{1}{2}^{\prime}, \quad O \wedge 1-\bar{\imath}=121^{\circ} 20 \frac{1}{4}^{\prime}$, Kokscharof; $\grave{c}: \bar{b}: \breve{a}=1 \cdot 64223: 1 \cdot 273634: 1$. $\stackrel{O}{O} \wedge 1-\check{\imath}=127^{\circ} 48^{\prime} ; O \wedge 1=115^{\circ} 35 \frac{1^{\prime}}{}{ }^{\prime} ;$ $1-\check{\imath} \wedge 1-\check{\imath}$, top $=75^{\circ} 35 \frac{1^{\prime}}{}{ }^{\prime}$. Crystals sometimes tabular ; often oblong prismatic, and elongated in the direction of either of the axes (as seen in the figures). Cleavage: $1, O$, but interrupted. The planes $I$ and $i-i$ often vertically striated, and $\frac{1}{2}-i$ horizontally. Also massive, granular, or hardly so. Sometimes stalactitic.
$\mathrm{H} .=2 \cdot 75-3 . \quad$ G. $=6 \cdot 12-6 \cdot 39$. Lustre highly adamantine in some specimens, in others inclining to resinons and vitreous. Color white, tinged yellow, gray, green, and sometimes blue. Streak uncolored. Transparent -opaque. Fracture conchoidal. Very brittle.

[^48]Diff.-Does not effervesce with acid like cerussite (lead carbonate); listinguished by blows pipe tests from other resembling species.


Obs.-This ore of lead was first observed by Monnet as a result of the decomposition of galenite, and it is often found in its cavities. Occurs in crystals at Leadhills; at Pary's mine in Anglesea; also at Melanoweth in Cornwall; in Derbyshire and in Cumberland: Clausthal, Zillerfeld, and Giepenbach in the Harz; near Siegen in Prussia; Schapbach in the Black Forest; in Sardinia; massive in Siberia. Andalusia, Alston Moor in Cumberland; in Australia. In the U. S., in large crystals at Wheatley's mine, Phenixville, Pa.; in Missouri lead mines ; at the lead mines of Southampton, Mass. ; at Rossie, N.Y. ; at the Walton gold mine, Louisa Co., Va. Compact in Arizona, and Cerro Gordo, Cal.

Dreelite.-Rhombohedral. H. $=3 \%$. G. $=3 \cdot 2-3 \cdot 4$. Color white. Composition given as $\mathrm{CaSO}_{4}+3 \mathrm{BaSO}_{4}$. Occurs in small crystals at Beaujeau, France; Badenweiler, Baden.

Dolerophanite (Scacchi).- $\mathrm{Cu}_{2} \mathrm{SO}_{5}$. In minute crystals. Monoclinic. Color brown. Vesuvius.
Hydrocyanite (Scacchi).-Anhydrous copper sulphate, CuSO ${ }_{4}$. Color sky-blue. Very soluble. Vesuvius.
Aphthitalite, Arcanite. $-\mathrm{K}_{2} \mathrm{SO}_{4}=$ Potash $54 \cdot 1$, sulphuric acid $45 \cdot 9=100$. Vesuvius.
Thenardite.-Sodium sulphate, $\mathrm{Na}_{2} \mathrm{SO}_{4}$. Spain; Vesuvius.

## LEADHILLITE.

Orthorhombic. $I \wedge I=103^{\circ} 16^{\prime}, O \wedge 1-\bar{\imath}=120^{\circ} 10^{\prime} ; \dot{c}: \bar{b} . \check{a}=1 \cdot 720$ a : $1 \cdot 2632$ : 1 . Hemihedral in $I$ and some other planes; hence monoclinic in aspect, or rhombohedral when in compound crystals. Clearage: i-乞 very perfect ; $i-\bar{\imath}$ in traces. Twins, f. 712, consisting of three crystals; twinning rlane, $1-i$ (see f. 298, p. 97); also parallel with $I$.
$\mathrm{H} .=2 \cdot 5 . \quad \mathrm{G} .=626-6 \cdot 44$. Lustre of $i-\iota$ pearly, other parts resinous, somewhat adamantine. Color white, passing into yellow, green, or gray. Streak uncolored. Transparent - translucent. Conchoidal fracture scarcely observable. Rather sectile.

Comp.-Formerly accepted formula, $\mathrm{PbSO}_{4}+3 \mathrm{PbCO}_{3}=$ Lead sulphate $27 \cdot 45$, lead carbonate $72 \cdot 55=$ 100. Recent investigations by Laspeyres (J. pr., Ch. II., v., 470 ; vii., 127 ; xiii., 370), and Hintze (Pogg. Ann., clii., 156), though not entirely accordant, give different results, both show the presence of some water. Laspeyres writes the formula empirically, $\mathrm{Pb}_{18} \mathrm{C}_{9} \mathrm{~S}_{5} \mathrm{O}_{61}+$ $5 \mathrm{H}_{2} \mathrm{O}$, and Hintze, $\mathrm{Pb}_{7} \mathrm{C}_{4} \mathrm{~S}_{2} \mathrm{O}_{21}+2 \mathrm{H}_{2} \mathrm{O}$. Analyses: 1. Laspeyres; 2, Hintze :

| $\mathrm{SO}_{3}$ | $\mathrm{CO}_{2}$ | PbO | $\mathrm{H}_{2} \mathrm{O}$ |
| :--- | :--- | :--- | :--- |
| 1. 8.14 | 8.08 | $81 \cdot y 1$ | $1.87=100$, Laspeyres. |
| 2.8 .17 | $9 \cdot 18$ | 80.80 | $2.00=100 \cdot 15$, Hintze. |

Pyr., etc.-B.B. intumesces, fuses at 1.5 , and turns yellow ; but white on cooling. Easily reduced on charcoal. With soda affords the reaction for sulphuric acid. Effervesces briskly in nitric acid, and leaves white lead sulphate undissolved.
Obs.-This ore has been found at Leadhills with other ores of lead; also in crystals at Red Gill, Cumberland, and near Taunton in Somersetshire ; at Iglesias, Sardinia (maxite).
Susannite.-Composition as for leadhillite, but form rhombohedral. Leadhills; Nertschinsk, Siberia.
Connellite.-Hexagonal. In slender needle-like blue crystals. Contains copper sulphate and copper chloride. Exact c mposition uncertain. Cornwall.

Caledonite.-Monoclinic (Schrauf). H. $=2 \cdot 5-3 . \quad$ G. $=6 \cdot 4$. Color bluish-green. $\quad \mathrm{R}_{2} \mathrm{SO}_{3}$ +aq (Flight), with $\mathrm{R}=\mathrm{Pb}: \mathrm{Cu}=7: 3$, or $5 \mathrm{PbSO}_{4}+3 \mathrm{H}_{4} \mathrm{CuO}_{2}+2 \mathrm{H}_{2} \mathrm{PbO}_{2}$. This requires : Sulphuric trioxide $19 \cdot 1$, lead oxide $65 \cdot \%$, copper oxide $11 \cdot 4$, water $4 \cdot 3=100$. Leadhills, Scotland; Red Gill; Retzbanya; Mine la Motte, Missouri.

Lanarkite. - Monoclinic. $\mathrm{H} .=2-2 \cdot \mathrm{~J}$. G. $=6 \cdot 3-6 \cdot 4$. Color pale yellow, or greenishwhite. Transparent. Composition as formerly accepted, $\mathrm{PbSO}_{4}+\mathrm{PbCO}_{3}$. New analyses by Flight, and by Pisani, show the absence of both carbon dioxide and water; composition accordingly $\mathrm{Pb}_{2} \mathrm{SO}_{5}=\mathrm{PbSO}_{4}+\mathrm{PbO}$, which requires : Lead sulphate $57 \cdot 6$, lead oxide $42 \cdot 4=100$. Leadhills; Siberia, etc.

## GLAUBERITE.

Monoclinic. $C=68^{\circ} 16^{\prime}, \quad I \wedge I=83^{\circ} 20^{\prime}, O \wedge 1-\grave{\imath}=136^{\circ} 30^{\prime} ; \dot{c}: b: a$ $=0.8454: 0.8267: 1$. Cleavage: $O$ perfect.

$$
\mathrm{H} .=2 \cdot 5-3 . \quad \mathrm{G} .=2 \cdot 64-2 \cdot 85 \text {. Lustre vitreous. Color }
$$

 pale yellow or gray; sometimes brick-red. Streak white. Fracture conchoidal; brittle. Taste slightly saline.

Comp. $-\mathrm{Na}_{2} \mathrm{CaS}_{2} \mathrm{O}_{8}=$ Sulphur trioxide $57 \cdot 6$, lime $20 \cdot 1$, soda $22 \cdot 3=$ 100.

Pyr., etc.-B.B. decrepitates, turns white, and fuses at 1.5 to a white enamel, coloring the flame intensely yellow. On charcoal fuses in O.F. to a clear bead ; in R.F. a portion is absorbed by the charcoal, leaving an infusibe hepatic residue. With soda on charcoal gives the reaction for sulphur. Soluble in hydrochloric acid. In water it loses its transparency, is partially dissolved, leaving a residue of calcium sulphate, and in a large excess this is completely dissolved. On long exposure absorbs moisture and falls to pieces.

Obs.-In crystals in rock salt at Viila Rubia in New Castile; also at Aussee in Upper Austria ; in Bavaria ; at the salt mines of Vic in France; and at Borax Lake, California; Province of Tarapaca, Peru.

## Hyprous Sulpiates.

## MIRABILITE. Glauber Salt.

Monoclinic. $\quad C=72^{\circ} 15^{\prime}, I \wedge I=86^{\circ} 31^{\prime}, O \wedge 1-i=130^{\circ} 19^{\prime} ; \dot{c}: b: i$ $=1 \cdot 1089: 0.8962: 1$. Cleavage : i-i perfect. Usually in efflorescent crusts
$\mathrm{H} .=1 \cdot 5-2 . \quad \mathrm{G} .=1 \cdot 481$. Lustre vitreous. Color white. Transparentopaque. Taste cool, then feebly saline and bitter.

Comp. $-\mathrm{Na}_{2} \mathrm{SO}_{4}+10 \mathrm{aq}=$ Sulphur trioxide $24 \cdot 8$, soda $19 \cdot 3$, water $55 \cdot 9=100$.
Pyr., etc.-In the closed tube much water; gives an intense yellow to the flame. Very soluble in water ; the solution gives with barium salts the reaction for sulphuric acid. Falls to powder on exposure to the air, and becomes anhydrous.

Obs.-Occurs at Ischl and Hallstadt; also in Hungary ; Switzerland; Italy; at Guipuzcoa in Spain, etc. ; at Kailua on Hawaii; at Windsor, Nova Scotia ; also near Sweetwater River, Rocky Mountains.

Mascagnite, Boussingaultite (cerbolite), Lecontite, and Goanovulite are hydrous sulphates containing ammonium.

## GYPSUIM.

Monoclinic. $C=66^{\circ} 14^{\prime}$, if the vertical prism $I$ (see f. 716) correspond to the cleavage prism (second cleavage). and the basal plane $O$ to the direction of the third cleavage. $I \wedge I=133^{\circ} 28^{\prime}, 1 \cdot \hat{\wedge} 1-\grave{\imath}=128^{\circ} 31^{\prime}$; $\dot{c}: b: \grave{a}=0.9: 2 \cdot 4135: 1$. $O \wedge \wedge 1=125^{\circ} 35^{\prime}, O \wedge 2-\grave{\imath}=145^{\circ} 41^{\prime}, 1 \wedge 1=$ $143^{\circ} 42^{\prime}, 2-i \wedge 2-i=111^{\circ} 42^{\prime}$.

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Cleavage: (1) $i-\hat{\imath}$, or clinodiagonal, eminent, affording easily smooth polished folia; (2) $I$, imperfect, fibrous, and often apparent in internal rifts or linings, making with $O$ (or the edge $2-i / 2-i$ ) the angles $66^{\circ} 14^{\prime}$, and $113^{\circ}$ $46^{\prime}$, corresponding to the obliquity of the fundamental prism; (3) O, or basal, imperfect, but affording a nearly smooth surface. Twins: 1. Twin-ning-plane $O$ common (f. 717); also $1-i$, or edge $1 / 1$. Simple crystals often with warped as well as curved surfaces. Also fuliated massive; lamellar stellate ; often granular massive ; and sometimes nearly impalpable.
$H .=1 \cdot 5$-2. G. $=2 \cdot 314-2 \cdot 328$, when pure crystals. Lustre of $i-i$ pearly and shining, other faces subvitreous. Massive varieties often glistening, sometimes dull earthy. Color usually white; sometimes gray, flesh-red, honey-yellow, ochre-yellow, blue ; impure varieties often black, brown, red or reddish-brown. Streak white. Transparent-opaque.

Var.-1. Crystallized, or Selenite; either in distinct crystals or in broad folia, the folla sometimes a yard across and transparent throughout. 2. F'ibrous; coarse or fine. (a) Satia spar, when fine-fibrous a varrety which has the pearly opalescence of moonstone ; (b) plumose, when radiately arranged. 3. Massive; Alabaster, a fine-grained variety, either white or delicately shaded; scaly-granulırr; earthy or rock-gypsum; a dull-colored rock, often impura with clay or calcium carbonate, and sometimes with anhydrite.

Comp.-CaSO $+2 a q=$ Sulphur trioxide $46 \%$, lime $32 \cdot 6$, water $20 \cdot 9=100$.
Pyr., etc.-In the closed tube gives off water and becomes opaque. Fuses at 2.5-3, coloring the flame reddish-yellow. For other reactions, see Aniydrite, p. 389. Ignited at a temperature not exceeding $260^{\circ} \mathrm{C}$., it again combines with water when moistened, and becomes firmly solid. Soluble in hydrochloric acid, and also in 400 to 500 parts of water.

Diff.-Characterized by its softness; it does not effervesce nor gelatinize with acids. Some varieties resemble heulandite, stilbite, talc, etc.; and in its fibrous forms it is like some calcite.

Obs.-Gypsum often forms extensive beds in connection with various stratified rocks, especially limestone, and marlytes or clay beds. It occurs occasionally in crystalline rocks. It is also a product of volcanoes; produced by the decomposition of pyrite when line is present ; and often about sulphur springs; also deposited on the evaporation of sea-water and brines, in which it exists in solution.

Fine specimens are found in the salt mines of Bex in Switzerland; at Hall in the Tyrol; in the sulphur mines of Sicily ; in the gypsum formation near Oçana in Spain; in the clay of Shotover Hill, near Oxford; at Montmartre, near Paris. A noted locality of alabaster occurs at Castelino, 35 m . from Leghorn. In the U. S. this species occurs in extensive beds in N. York, Ohio, Illinois, Virginia, Tennessee, and Arkansas; it is usually associated with salt springs. Also in Nova Scotia, Peru, etc. It is characteristic of the so-called triassic, or red $b \epsilon d s$, of the Rocky Mountain region; also of the Cretaceous in the west, particularly of the clays of the Fort Pierre group, in which it occurs in the form of transparent plates.

Handsome selenite and snowy gypsum occur in $N$. York, near Lockport; also near Camillus, Onondaga Co. In Maryland, on the St. Mary's, in clay. In Olio, large transparent crystals have been found at Poland and Canfield, Trumbull Co. In Tenn., selenite and alabaster in Davidson Co. In Kentucky, in Mammoth Cave, in the form of rosettes, etc. In $N$. Scotia, in Sussex, King's Co., large crystals, often containing much symmetrically disseminated sand (Marsh).

Plaster of Paris (or gypsum which has been heated and ground up) is used for making moulds, taking casts of statues, medals, etc. ; for .producing a hard finish on walls; also in the manufacture of artificial marble, as the scagliola tables of Leghorn, and in the glazing of porcelain.

## POLYHALITE.

Monoclinic (?). A prism of $115^{\circ}$, with acute edges truncated. Usually in compact fibrous masses.
H. $=2 \cdot 5-3$. G. $=2 \cdot 7689$. Lustre resinons or slightly pearly. Streak red. Color flesh- or brick-red, sometimes yellowish. Translucent-opaque Taste bitter and astringent, but very weak.

Comp. $-2 \mathrm{RSO}_{4}+\mathrm{aq}$, where $\mathrm{R}=\mathrm{Ca}: \mathrm{Mg}: \mathrm{K}_{2}$ in the ratio 2:1:1; that is, $\mathrm{K}_{2} \mathrm{MgCa}_{2} \mathrm{~S}_{4} \mathrm{O}_{18}$ $+2 \mathrm{aq}=$ Calcium sulphate $45 \cdot 2$, magnesium sulphate $19 \cdot 9$, potassium sulphate $2 \delta^{\circ} \cdot 9$, water $6 \cdot 0=100$.

Pyr., etc.-In the closed tube gives water. B.B fuses at $1 \cdot 5$, colors the flame yellow. On charcoal fuses to a reddish globule, which in R.F. becornes white, and on cooling has a saline bepatic taste; with soda like glauberite. With fluor does not give a clear bead. Partially scluble in water, leaving a residue of calcium sulphate, which dissolves in a large amount of water

Obs-Occurs at the mines of Ischl, Ebensee, Aussee, Hallstatt, and Hallein in Austria, with commou salt, gypsum, and anhydrite ; at Berchtesgaden in Bavaria; at Vic in Lorraine.

The name Polyhalite is derived from $\pi v \lambda \dot{v} s$, many, and ${ }^{\circ} \lambda s, s a l t$, in allusion to the number of salts in the constitution of the mineral.

Syngenite, v. Zephrrovich; Kaluszite, Rumpf.-Near polyhalite. Composition RSO ${ }_{4}+$ aq , with $\mathrm{R}=\mathrm{Ca}: \mathrm{K}_{2}=1: 1$, that is, $\mathrm{K}_{2} \mathrm{CaS}_{8}+\mathrm{aq}=$ Potassium sulphate $53 \cdot 1$, calcium sul. phate $41 \cdot 4$, water $5 \cdot 5=100$. Monoclinic. Occurs in small tabular crystals in cavities in halito at Ralusz, East Galicia.

Kieserite. $-\mathrm{MgSO}_{4}+\mathrm{aq}=$ Sulphur trioxide $58 \cdot 0$, magnesia $28 \cdot 0$, water $13 \cdot 0=100$. Stassfurt.

Picromerite is $\mathrm{K}_{2} \mathrm{MgS}_{2} \mathrm{O}_{8}+6 \mathrm{aq}=$ Sulphur trioxide $39 \cdot 8$, magnesia $9 \cdot 9$, potash $23 \cdot 4$, water $26 \cdot 9=100$. Vesuvius; Stassfurt.

Bloedite.-Composition $\mathrm{Na}_{2} \mathrm{MgS}_{2} \mathrm{O}_{8}+4 \mathrm{aq}=$ Sulphur trioxide $47 \cdot 9$, magnesia $12 \cdot 0$, soda $18 \cdot 6$, water $21 \cdot \bar{y}=100$. Salt mines of Ischl; also in the Andes. Sinonyite (Tychermak) is identical.

Leweite. - $2 \mathrm{Na}_{2} \mathrm{MgS}_{2} \mathrm{O}_{8}+5 \mathrm{aq}=$ Sulphur trioxide $52 \cdot 1$, magnesia $13 \cdot 0$, soda $20 \cdot 2$, water $14 \cdot 7=100$. From Ischl.

## EPSOMITE. Epsom Salt. Bittersalz, Germ.

Orthorhombic, and generally hemihedral in the octahedral modifications. $I \wedge I=90^{\circ} 34^{\prime}, O \wedge 1-\bar{\imath}=150^{\circ} 2^{\prime} ; \dot{c}: \bar{b}: \breve{a}=0.5766: 1 \cdot 01: 1$. 1- $-\stackrel{\iota}{\wedge} 1-\check{\iota}$, basal, $=59^{\circ} 27^{\prime}, 1-\bar{\imath} \wedge 1-\bar{\imath}$, basal, $=59^{\circ} 56^{\prime}$. Cleavage: brachydiagonal, perfect. Also in botryoidal masses and delicately tibrous crusts.
H. $=2 \cdot 25$. G. $=1 \cdot 751 ; 1 \cdot 685$, artificial salt. Lustre vitreous-earthy. Streak and color white. Transparent-translucent. Taste bitter and saline.

Comp. $-\mathrm{MgSO}_{4}+7 \mathrm{Faq}$, when pure $=$ Sulphur trioxide $32 \cdot 5$, magnesia $16 \cdot 3$, water $51 \cdot 2=100$.
Pyr., etc.-Liquifies in its water of crystallization. Gives much water in the closed tube at a high temperature; the water is acid. B.B. on charcoal fuses at first, and finally yields an infusible alkaline mass, which, with cobalt solution, gives a pink color on ignition. Very soluble in water, and has a very bitter taste.

Obs.-Common in mineral waters, and as a delicate fibrous or capillary efflorescence on rocks, in the galleries of mines, and elsewhere. In the former state it exists at Epsom, England, and at Sedlitz and Saidschutz in Bohemia. At Idria in Carniola it occurs in silky fibres, and is hence called hairsalt by the workmen. Also obtained at the gypsum quarries of Montmartre, near Paris; in Aragon and Catalonia in Spain; in Chili ; found at Vesuvius, etc.

The floors of the limestone caves of Kentucky, Tennessee. and Indiana, are in many instances covered with epsomite, in minute crystals, mingled with the earth. In the Mammoth Cave, Ky., it adheres to the roof in loose masses like snowballs.

Fauserite.-A hydrous manganese-magnesium sulphate. Hungary.

## Copperas Group.

CHALCANTHITE. Blue Vitriol. Kupfervitriol, Germ.
Triclinic. $O \wedge I=109^{\circ} 32^{\prime}, O \wedge I^{\prime}=127^{\circ} 40^{\prime}, I \wedge I^{\prime}=123^{\circ} 10^{\prime}, O \wedge 1$ $=125^{\circ} 38^{\prime}, O \wedge i-\bar{\imath}=120^{\circ} 50^{\prime}, O \wedge i-\check{\imath}=103^{\circ} 27^{\prime}$. Cleavage: $I$ imperfect, $I^{\prime}$ very imperfect. Occurs also anorphous, stalactitic, reniform.
II. $=2 \cdot 5$. G. $=2 \cdot 213$. Lustre vitreous. Color Berlin-blue to sky-blue, of different shades; sometimes a little greenish. Streak uncolored. Sub-transparent-translncent. Taste metallic and nauseous. Somewhat brittle.

[^49]are the Rammelsberg mine, near Goslar, in the Harz; Fahlun in Sweden; at Parys mine; Anglesey; at various mines in Co. of Wicklow; Rio Tinto mine, Spain. Found at the Hiwassee copper mine, and other mines, in Polk Co., Tennessee ; at the Canton mine, Georgia; at Copiapo, Chili, with stypticite.

When purified it is employed in dyeing operations, and in the printing of cotton and linen, and for various other purposes in the arts. It is manufactured mostly from old sheathing, copper trimmings, and refinery scales.

Other vitriols are:-Melanterite, iron vitriol ; Pisanite, iron-copper vitriol; Goslarite, zinc vitriol ; Bieberite, cobalt vitriol ; Morenosite, nickel vitriol ; Cupromagnesite, copper-magnesium vitriol (Vesuvius). These are all alike in containing 7 molecules of water of crystallization.

Alunogen (Haarsalz, Germ.).-AlS $\mathrm{S}_{3} \mathrm{O}_{12}+18 \mathrm{aq}=$ Sulphur trioxide $36 \cdot 0$, alumina $15 \cdot 4$, water $48 \cdot 6=100$. Taste like that of alum. Vesuvius; Königsberg, Hungary.

Coquimbite. $-\mathrm{FeS}_{3} \mathrm{O}_{12}+9 \mathrm{aq}=$ Sulphur trioxide $42 \cdot 7$, iron sesquioxide $28 \cdot 5$, water $28 \cdot 8=$ 100. Coquimbo, Chili.

Ettringite (Lehmann).—Analysis, $\mathrm{SO}_{3} 16 \cdot 64, \mathrm{AlO}_{3} 7 \cdot 76, \mathrm{CaO} 27 \cdot 27, \mathrm{H}_{2} \mathrm{O} 45 \cdot 8$. In hexagonal needle-like crystals from the lava at Ettringen, Laacher See.

## Alum and Halotrichite Groups.

Here belong: Tsciermigite, ammonium alum. Kalinite, potassium alum, or common alum. Mendozite, sodium alum. Piceeringite, magnesium alum. Apjohnite, manganese alum. Bosjemannite, mangano-magnesium alum. Halotricuite, iron alum. also Remerite, and Voltaite.

## COPIAPITE.

Hexagonal (?). Loose aggregation of crystalline scales, or granular massive, the scales rhombic or hexagonal tables. Cleavage: basal, perfect. Incrusting.
H. $=1 \cdot 5$. G. $=2 \cdot 14$, Borcher. Lustre pearly. Color sulphur-yellow, citron-yellow. Translucent.
 sesquioxide $33 \cdot 5$, water $24 \cdot 5=100$.

Pyr., etc.-Yields water, and at a higher temperature sulphuric acid. On charcoal becomes magnetic, and with soda affords the reaction for sulphur. With the fluxes reactions for iron. In water insoluble.

Obs.-Common as a result of the decomposition of pyrite at the Rammelsberg mine, near Goslar in the Harz, and elsewhere.
This species is the yellow copperas long called misy, and it might well bear now the name Misylite.

Raimondite.-Composition $\mathrm{Fe}_{2} \mathrm{~S}_{3} \mathrm{O}_{1 \mathrm{~s}}+7 \mathrm{aq}$. Fibroferrite (stypticite).-Composition $\mathrm{FeS}_{2} \mathrm{O}_{9}+10 \mathrm{aq}$.

- Botryogen is red iron vitriol, exact composition uncertain. Fahlun, Sweden. BarthoLomite, West Indies, is related.

Iilleite.- $\mathrm{Fe} \mathrm{S}_{3} \mathrm{O}_{12}+12 \mathrm{aq}$. Occurs as a yellow efflorescence on graphite from Mugrau. Bohemia (Schrauf).

## ALUMINITE.

Reniform, massive; impalpable.
H. $=1-2$. G. $=1 \cdot 66$. Lustre dull, earthy. Color white. Opaque.

Fracture earthy. Adheres to the tengue; meagre to the touch

Comp. $-\mathrm{AlSO}_{6}+9$ aq $=$ Sulphur trioxide $23 \cdot 2$, alumina $29 \cdot 8$, water $47 \cdot 0=100$.
Pyr., etc.-In the closed tube gives much water, which, at a high temperature, becomen acid from the evolution of sulphurous and sulphuric oxides. B.B. infusible. With cobalt solution a fine blue color. With soda on charcoal a hepatic mass. Soluble in acids.

Obs.-Occurs in connection with beds of clay in the Tertiary and Post-tertiary formatious. Found near Halle; at Newhaven, Sussex; Epernay, in Lunel Vieil, and Auteuil, in France

Werthemanite.-AlSO ${ }_{6}+3$ aq. G. $=2 \cdot 80$. Occurs near Chachapoyas, in Peru.
Alunite, Alaunstein, Germ.-Composition $\mathrm{K}_{2}+1_{3} \mathrm{~S}_{4} \mathrm{O}_{22}+6 \mathrm{aq}$. Rhombohedral. Also massive, fibrous. Forms seams in trachyte and allied rocks. Tolfa, near Rome; Tuscany; Hungary ; Mt. Dore, France, etc.

Lö̈IGITE.--Same composition as alunite, but contains 3 parts more of water. Tabrze, Silesia.

LINARITE. Bleilasur, Kupferbleispath, Germ.
Monoclinic. $C=77^{\circ} 27^{\prime} ; I \wedge I$, over $i-i,=61^{\circ} 36^{\prime}, O \wedge 1-\grave{\imath}=141^{\circ} 5^{\prime}$, $c: b: \grave{a}=0 \cdot 48134: 0 \cdot 5819: 1$, Hessenberg. Twins: twinning-plane $i-i$ common; $O \wedge O^{\prime}=154^{\circ} \quad 54^{\prime}$. Cleavage : $i-i$ very perfect; $O$ less so.
H. $=2 \cdot 5 . \quad \mathrm{G} .=5.3-5 \cdot 45$. Lustre vitreous or adamantine. Color deep azure-blue. Streak pale blue. Translucent. Fracture conchoidal. Lrittle.

Comp. $-\mathrm{PbCuSO}_{5}+\mathrm{aq}=(\mathrm{Pb}, \mathrm{Cu}) \mathrm{SO}_{4}+\mathrm{H}_{2}(\mathrm{~Pb}, \mathrm{Cu}) \mathrm{O}_{2}=$ Sulphur trioxide 20.0 , lead oxide 55.7 , copper oxide $19 \cdot 8$, water $4 \cdot 5=100$.

Pyr., etc.-In the closed tube yields water and loses its blue color. B.B. on charcoal fuses easily to a pearl, and in R.F. is reduced to a metallic globule which by continued treatment coats the coal with lead oxide, and if fused boron trioxide is added yields a pure globule of copper. With soda gives the reaction for sulphur. Decomposed with nitric acid, leaving a white residue of lead sulphate.

Obs.-Formerly found at Leadhills. Occurs at Roughten Gill, Red Gill, etc., in Cumberland ; near Schneeberg, rare ; in Dillenburg; atRetzbanya; in Nertschinsk; and near Beresof in the Ural ; and supposed formerly to be found at Linares in Spain, whence the name.

## BROCHANTITE.

Monoclinic. $C=89^{\circ} 27 \frac{1}{2}^{\prime} . \quad I \wedge I=104^{\circ} 6 \frac{1}{2}^{\prime}, O \wedge 1-\grave{\imath}=154^{\circ} 12 \frac{1_{2}^{\prime}}{} ; \dot{c}:$ $b: \grave{a}=0.61983: 1.28242: 1$. Schrauf distinguishes four types of forms : I. Brochantite from Retzbanya (two varieties), also from Cornwall and Russia, triclinic ; II. Warringtonite from Cornwall, a third variety from Retzbanya, monoclinic (?); III. Brochantite from Nischne-Tagilsk, mono-clinic-triclinic ; IV. Königine from Russia, and a fourth variety from Retzbanya, monoclinic (or orthorhombic).

Also in groups of acicular crystals and drusy crusts. Cleavage : $i-i$ very perfect; I in traces. Also massive; reniform with a columnar structure.
H. $=3 \cdot 5-4$. G. $=3 \cdot 78-3 \cdot 87$, Magnus ; 3•9069, G. Rose. Lustre vitreous; a little pearly on the cleavage-face. Color emerald-green, blackish-green. Streak paler green. Trausparent-translucent.

Comp. $-\mathrm{Cu}_{4} \mathrm{SO}_{7}+3 \mathrm{H}_{2} \mathrm{O}=\mathrm{CuSO}_{4}+3 \mathrm{H}_{2} \mathrm{CuO}_{2}=$ Sulphur trioxide $17 \cdot 71$, copper oxide $70 \cdot 34$, water $11.95=100$. This formula belongs to type IV., above; the warringtonite corresponds nore nearly to $\mathrm{CuSO}_{4}+3 \mathrm{H}_{2} \mathrm{CuO}_{4}+\mathrm{H}_{2} \mathrm{O}$, and the existence of other varieties has been also assumed.

Pyr., etc.-Yiclds water, and at a higher temperature sulphuric acid, in the closed tube, and becomes black. B.B. fuses, and on charcoal affords metallic copper. With soda gives the reaction for sulphuric acid.

Cbs.-Occurs at Gumeschersk and Nischne-Tagilsk in the Ural ; the Königine (or Königite) was from Gumeschevsk; near Roughten Gill, in Cumberland; in Cornwall (in part warringtonite) ; at Retzbanya ; in Nassan; at Krisuvig in Iceland (krisuvigite); in Mexico (brongnartine) ; in Chili, at Andacollo ; in Australia.

Named after Brochant de Villiers.
LaNGITE. - $\mathrm{CuSO}_{4}+2 \mathrm{H}_{2} \mathrm{CuO}_{2}+2$ aq. In crystals and concretionary crusts of a blue color. $\mathrm{G} .=3 \cdot 5 . \quad$ Cornwall.

Cyanotriciite, Lettsomite. Kupfersammterz, Germ.-In velvety druses. Color blue. A hydrous sulphate of copper and aluminum. Moldava in the Banat. Woodwardite, near the above.

Krönkite.- $\mathrm{CuSO}_{4}+\mathrm{Na}_{2} \mathrm{SO}_{4}+2 \mathrm{aq}=$ Copper sulphate $47 \cdot 2$, sodium sulphate $42 \cdot 1$, water $10.7=100$. In irregular crystalline masses of a coarse fibrous structure, prismatic. Color azure-blue. Moist to the touch. Found in the copper mines near Calama, Bolivia. (Domeyko.)

Philifipite.- $\mathrm{CuSO}_{4}+\mathrm{FeS}_{3} \mathrm{O}_{12}+$ naq. In irregular fibrous masses, not prismatic. Color blue. In the cordilleras of Condes, Santiago, Chili. (Domeyko.)

Enysite.-Occurs in stalactitic forms in a cave. $\mathrm{H}_{\mathrm{o}}=2-2 \cdot 4$. G. $=1 \cdot 59$. Color bluishgreen. B.B. infusible. Analysis: $\mathrm{SO}_{3} 8 \cdot 12, \mathrm{AlO}_{3} 29 \cdot 85, \mathrm{CuO} 16.91, \mathrm{CaO} 1 \cdot 35, \mathrm{H}_{3} \mathrm{O} 39 \cdot 42$, $\mathrm{SiO}_{2} 3 \cdot 40, \mathrm{CO}_{2} 1 \cdot 05=100$. Near St. Agnes, Cornwall. (Collins, Min Mag., 1. p. 14.)

Uranium-sulphates. - There are included here johannite, uranochalcite, medjidite, zippeite, voglianite, uraconite. These are secondary products found with other uranium minerals at Jowchimsthal.

## Tellurates.

## MONTANITE.

Incrusting; without distinct crystalline structure.
Soft and earthy. Lustre dull to waxy. Color yellowish to white. Opaque.

Comp. $-\mathrm{Bi}_{2} \mathrm{TeG}_{6}+2 \mathrm{aq}=$ Tellurium trioxide $26 \cdot 1$, bismuth oxide $68 \cdot 6$, water $5 \cdot 3=100$.
Pyr., etc.-Yields water in a tube when heated. B.B. gives the reactions of bismuth and tellurium. Soluble in dilute hydrochloric acid.

Obs.-Incrusts tetradymite, at Highland, in Montana; Davidson Co., N. C.

## 7. CARBONATES.

## Anhydrous Carbonates.

## Calcite Group.

CALCITE. Calc Spar. Kalkspath, Grm.
Rhombohedral. $R \wedge R$, terminal, $=105^{\circ} 5^{\prime}, O \wedge R=135^{\circ} 23^{\prime} ; d=$ 0.8543. Cleavage: $R$ highly perfect.


Angles of Rhombohedrons.


Twins: (1) Twinning-plane basal (or parallel to $O$ ). (2) $R$, the vertical axes of the two forms nearly at right angles. (3) $-2 R$. (4) $-\frac{1}{2} R$, the vertical axes of the two forms inclined to one another $127^{\circ} 34^{\prime}$. (5) Prismatic plane $i-2$. (6) plane $i$ (see p. 95).

Also fibrous, both coarse and fine; sometimes lamellar ; often granular ; from coarse to impalpable, and compact to earthy. Also stalactitic, tuberose, nodular, and other imitative forms.
$\mathrm{H} .=2 \cdot 5-3.5$; some earthy kinds (chalk, etc.) 1. G. $=2 \cdot 508-2 \cdot 778$; pure crystals, 2.7213-2.7234, Beud. Lustre vitreous-subvitreous-earthy. Color white or colorless; also various pale shades of gray, red, green, blue, violet, yellow; also brown and black when impure. Streak white or grayish. Transparent-opaque. Fracture usually conchoidal, hut obtained with difficulty when the specimen is crystallized. Double refraction strong.


Comp., Var.-Calcite is calcium carbonate, $\mathrm{CaCO}_{3}=$ Carbon dioxide 41 , lime $56=100$. Part of the calcium is sometimes replaced by magnesium, iron, or manganese, more rarely by strontium, barium, zinc, or lead.

The varietics are very numerous, and diverse in appearance. They depend mainly on the following points: (1) differences in crystallization; (2) in structural condition, the extremea being perfect crystals and earthy massive forms; (3) in color, diaphaneity, odor on fristion, due to impurities; (4) in modes of origin.

1. Crystallized. Crystals and crystallized masses afford easily cleavage rhombohedrons; and when transparent they are called Icelind Spar, and also Doubly-r efracting Spar (Doppelspath, Germ.).

The crystals vary in proportions from broad tabular to moderately slender acicular, and take a great diversity of forms. But the extreme kinds so pass into one another through those that are intermediate that no satisfactory classification is possible. Many are stout or short in shape becau*? normally so. But other forms that are long tapering in their full develop-
ment occur short and stout because abbreviated by an abrupt termination in a broad $o$, or an obtuse rhombohedron (as $-\frac{1}{2}$ or $R$ ), or a low scalenohedron (as $\frac{\frac{1}{4}^{3}}{}$ ), or a combination of these forms; and thus the crystals having essentially the same combinations of planes vary greatly in shape. The acute scalenohedrons like f. 724, are called dog-tooth spar.

Fontainebleau iimestone. Crystals of the form in f. 719 c , from Fontainebleau and Nerr.ours, France, containing a large amount of sand, some 50 to 63 p. c. Similar sandstone crystals occur at Sievring, near Vienna, and elsewhere. Pseudomorphous scalenohedrons of sandstone, after calcite, are found near Heidelberg.

Satin Spar; fine fibrous, with a silky lustre. Resembles fibrous gypsum, which is also called satin spar, but is much harder and effervesces with acids. Argentine (Schieferspath), a pearly lamellar calcite, the lamellæ more or less undulating ; color white, grayish. yellowish, or reddish. Aphrite, in its harder and more sparry variety (Schaumspath) is a foliated white pearly calcite, near argentine; in its softer kinds (Schaumerde, Silvery Chabk, Ecume de Terre H.) it approaches chalk, though lighter, pearly in lustre, silvery-white or yellowish in color, soft and greasy to the touch, and more or less scaly in structure.
2. Massive Varieties. Granular limestone (Saccharoidal limestone, so named because like loafsugar in fracture). The texture varies from quite coarse to very fine granular, and the latter passes by imperceptible shades into compact limestone. The colors are various, as white, yellow, reddish, green, and usually they are clouded and give a handsome effect when the material is polished. When such limestones are fit for polishing, or for architectural or ornamental use, they are called marbles. Statuary marble is pure white, fine grained, and firm in texture. Hard compact limestone, varies from nearly pure white, through grayish, drab, buff, yellowish. and reddish shades, to bluish-gray, dark brownish-gray, and black, and is sometimes variously veined. The colors dull, excepting ochre-yellow and ochre-red varieties. Many kinds make beautiful marble when polished

Shell-marble includes kinds consisting largely of fossil shells. Ruin-marble is a kind of compact calcareous marl, showing, when.polished, pictures of fortifications, temples, etc., in ruins, due to infiltration of oxide of iron. Lithographic stone is a very even grained compact limestone, usually of buff or drab color; as that of Solenhofen. Breccia marble is made of fragments of limestone cemented together, and is often very beautiful when the fragments are of different colors, or are imbedded in a base that contrasts well. The colors are very various. Pudding stone marble consists of pebbles or rounded stones cemented. It is often called, improperly, breccia marble.

Hydraulic limestone is an impure limestone. The varieties in the United States contain 20 to 40 p . c. of magnesia, and 12 to 30 p . c. of silica and alumina.

Soft compact limestone. Chalk is white, grayish-white, or yellowish, and soft enough to leare a trace on a board. The consolidation into a rock of such softness may be owing to the fact that the material is largely the hollow shells of rhizopods. Calcareous marl (Mergelkalk, Germ.) is a soft earthy deposit, often hardly at all consolidated, with or without distinct fragments of shells; it generally contains much clay, and graduates into a calcareous clay.

Concretionarg massive. Oölite (Rogenstein, Germ.) is a granular limestone, but its grains are minute rounded concretions, looking somewhat like the roe of a fish, the name coming from ' $\omega \mathrm{ov}$, egg. It occurs among all the geological formations, from the Lower Silurian to the most recent, and it is now forming about the coral reefs of Florida. Pisolite (Erbsentein, Germ.) consists of concretions as large often as a small pea, or even larger, the concretions having usually a distinct concentric structure. It is formed in large masses in the vicinity of the Hot Springs at Carlsbad in Bohemia.

Deposited from calcareous springs, streams, or in caverns, etc. (a) Stalactites are the calcareous cylinders or cones that hang from the roofs of limestone caverns, and which are formed from the waters that drip through the roof; these waters hold some calcium bicarbonate in solution, and leave calcium carbonate to form the stalactite when evaporation takes place. Stalactites vary from trinsparent to nearly opaque; from a granular crystalline structure to a radiating fibrous; from a white color and colorless to yellowish-gray and brown. (b) Stalagmite is the same material covering the floors of caverns, it being made from the waters that drop from the roofs, or from sources over the bottom or sides; cones of it sometimes rise frou the floor to meet the stalactites above.
(c) Calc-sinter, I'ravertine, Calc Tufa. Travertine (Confetto di Tivoli) is of essentially the same origin with stalagmite, but is distinctively a deposit from springs or rivers, especialiy where in large deposits, as along the river Anio, at Tivoli, near Rome, where the deposit is scores of feet in thickness. It has a very cavernous and irregularly banded structure, owing to its mode of formation.
(d) Agaric mineral; Rock-milk (Bergmilch, Montmilch, Germ.) is a very soft, white material, breaking easily in the fingers, deposited sometimes in caverns, or about sources holding lime in sclution.
(\&) Rock-meal (Bergmehl, Germ.) is white and light, like cotton, becoming a powder on the slightest pressure. It is an efflorescence, and is common near Paris, especially at the quarries of Nanterre.

Pyr., etc.-In the closed tube sometimes decrepitates, and, if containing metallic oxides may change its color. B.B. infusible, but becomes caustic, glows, and colors the flame red after ignition the assay reacts alkaline; moistened with hydrochloric acid imparts the characteristic lime color to the Hame. In borax dissolves with effervescence, and if saturated, yields on cooling an opaque. milk-white, crystalline bead. Varieties containing metallic oxides color the borax and salt of phosphorus beads accordingly. With soda on platinum foil fuses to a clear mass; on charcoal it at first fuses, but later the soda is absorbed by the coal, leaving an infusible and strongly luminous residue of lime. In the solid mass effervesces when moistened with bydrochloric acid, and fragments dissolve with brisk effervescence even iu cold acid.

Diff.-Distinguishing characters : perfect rhombohedral cleavage; softness, can be scratched with a knife ; effervescence in cold dilute acid; infusibility. Less hard and of lower specifio gravity than aragonite.

Obs.-Andreasberg in the Harz is one of the best European localities of crystallized calcite ; there are other localities in the Tyrol, Styria, Carinthia, Hungary, Saxony, Hesse Darmstadt (at Auerbach), Hesse Cassel, Norway, France, and in England in Derbyshire, Cumberland, Cornwall; Scotland; in Iceland.

In the U. States prominent localities are : in N. York, in St. Lawrence and Jefferson Cos., especially at the Rossie lead mine ; in Antwerp; dog-tooth spar, in Niagara Co., near Lockport; near Booneville, Oneida Co.; at Anthony's Nose, on the Hudson; at Watertown, Agaric mineral; at Schoharie, fine stalactites in many caverns. In Conn., at the lead mine, Middletown In N. Jersey, at Bergen. In Virginia, at the celebrated Wier's cave, stalactile.s of great beauty; also in the large caves of Kentucky. At the Lake Superior copper mines, splendid crystals often containing scales of native copper. At Warsaw, Illinois; at Quincy. Ill.; at Hazle Green, Wis. In Nova Scotia, at Partriage I.

## DOLOMITE.

Rhombohedral. $R \wedge R=106^{\circ} 15^{\prime}, O \wedge R=136^{\circ} 8 \frac{11^{\prime}}{} ; \quad \dot{c}=0.8322$. $R \wedge R$ varies between $106^{\circ} 10^{\prime}$ and $106^{\circ} 20^{\prime}$. Cleavage : $R$ perfect. Faces $R$ often curved, and secondary planes usually with horizontal striæ. Twins: similar to f. 733. Also in imitative shapes; also amorphous, granular, coarse or fine, and grains often slightly coherent.
I. $=3 \cdot 5-4 . \quad$ G. $=2 \cdot 8-2 \cdot 9$, true dulomite. Lustre vit-
 reous, inclining to pearly in some varieties. Color white, reddish, or green-ish-white ; also rose-red, greeu, brown, gray, and black. Subtransparent to trauslucent. Brittle.

Comp., Var.- $(\mathrm{Ca}, \mathrm{Mg}) \mathrm{CO}_{s}$, the ratio of $\mathrm{Ca}: \mathrm{Mg}$ in normal or true dolomite is $1: 1=\mathrm{Cal}$ cium carbonate 54.35 , magnesium carbonate 45.65 . Some kinds included under the name have other proportions; but this may arise from their being mixtures of dolomite with calcite or magnesite. Iron, manganess, and more rarely cobalt or zinc are sometimes present.

The varieties are the following:
Crystallized. P'earl spar includes rhombohedral crystallizations with curved faces. Columnar or fibrous. Granular constitutes many of the kinds of white statuary marble, and white and colored architectural marbles, names of some of which have been mentioned under calcite.

Convact mussive, like ordinary limestoue. Many of the limestone strata of the globe are here included, and much hydraulic limestone, noticed under calcite.

Ferriferous; Brown spar, in part. Contains iron, and as the proportion increases it graduates into ankerite (q. v.). The color is white to brown, and becomes brownish on exposure Lhrough oxidation of the iron. Manganiferous. Colorless to flesh-red. $R \wedge R=106^{\circ} 23^{\prime}$, $106^{\circ} 16^{\prime}$. Cobaltiferous. Colored reddish; G. =2 921 , Gibbs.

The varieties based on variations in the proportions of the carbonates are the following : (a) Normal dolomite, ratio of Ca to $\mathrm{Mg}=1: 1$, (b) ratio $1 \frac{1}{2}: 1=3: 2$; ratio=2:1; ratio 3 : 1 ; ratio $=5: 1$; ratio $1: 3$. The last $(f)$ may be dolomitic magnesite ; and the others, from
(b). dolomitic calcite, or calcite + dolomite. The manner in which dolomite is ofted mixed wilh calcite, forming its veins and its fossil shells (see below), shows that this is not intprobarile.
Pyr., etc.-B.B. acts like calcite, but does not give a clear mass when fused with soda on platinum foil. Fragments thrown into cold acid are very slowly acted upor, while in powder in warm acid the mineral is readily dissolved with effervescence. The ferriferous dolomites become brown on exposure.
Diff.--Resembles calcite, but generally to be distinguished in that it does not effervesce readily in the mass in cold acid.
Obs.-Massive dolomite constitutes extensive strata, called limestone strata, in various regions. Crystalline and compact varieties are often associated with serpentine and other magnesian rocks, and with ordinary limestones. Some of the prominent localities are at Salzburg; the Tyrol; Schemnitz in Hungary; Kapnik in Transylvania; Freiberg in Saxony; the lead mines at Alston in Derbyshire, etc.
In the U. States, in Vermont, at Roxbury. In Rhode Island, at Smithfield. In N. Jersey, at Hoboken. In N. York, at Lockport, Niagara Falls, and Rochester ; also at Glenn's Falls, in Richmond Co., and at the Parish ore bed, St. Lawrence Co.; at Brewster, Putnam Co.

Named after Dolomieu, who announced some of the marked characteristics of the rock in 1791-its not effervesoing with acids, while burning like limestone, and its solubility after heating in acids.

## ANKERITE.

Rhombohedral. $R \wedge R=106^{\circ} 7^{\prime}$, Zepharovich. Also crystalline massive, coarse or fine granular, and compact.
$\mathrm{H} .=3 \cdot 5-4$. G. $=2 \cdot 95-3 \cdot 1$. Lustre vitreous to pearly. Color white, gray, reddish. Translucent to subtranslucent.

Comp. $-\mathrm{CaCO}_{3}+\mathrm{FeCO}_{3}+x\left(\mathrm{CaMgC}_{2} \mathrm{O}_{6}\right)$. Here, according to Boricky, $x$ may have the values $\frac{1}{4}, 1, \frac{4}{3}, \frac{3}{2}, \frac{5}{3}, 2,3,4,5,10$. The varieties having the five higher values of $x$ he calls paran$k$ reite, while the others are normal ankerite. If $x=1$, the formula is equivalent to $2 \mathrm{CaCO}_{3}+$ $\cdot \mathrm{MgCO}_{3}+\mathrm{FeCO}_{3}$, and requires: Calcium carbonate 50, magnesium carbonate 21 , iron carbonate $29=100$. Manganese is also sometimes present.

Pyr., etc.-B.B. like dolomite, but darkens in color, and on charcoal becomes black and magnetic; with the fluxes reacts for iron and manganese. Soluble with effervescence in the acids.

Obs.-Occurs with siderite at the Styrian mines ; in Bohemia; Siegen; Schneeberg; Nova Scotia, etc.

## MAGNESTTE.

Rhombohedral. $\quad R \wedge R=107^{\circ} 29^{\prime}, O \wedge R=136^{\circ} 56^{\prime} ; \dot{c}=0.8095$. Cleavage: rhombohedral, perfect. Also massive; granular, to very compact. H. $=3 \cdot 5-4 \cdot 5 . \quad$ G. $=3-3 \cdot 08$, cryst. ; $2 \cdot 8$, earthy ; $3-3 \cdot 2$, when ferriferons. Lustre vitreous; fibrous varieties sometimes silky. Color white, yellowish or grayish-white, brown. Transparent-opaque. Fracture flat conchoidal.

Var.-Ferriferous, Breunerite; containing several p. c. of iron protoxide; G. $=3-3 \cdot \boldsymbol{2}$; white, yellowish, brownish, rarely black and bituminous; often becoming brown on exposure, and hence called Broon Spar.

Comp.-Magnesium carbonate, $\mathrm{MgCO}_{3}=$ Carbon dioxide $52 \cdot 4$, magnesia $47 \cdot 6=100$; but iron often replacing some magnesium.

Pyr., etc.-B. 13. resembles ealcite and dolomite, and like the latter is but slightly acted upon by cold acids; in powder is readily dissolved with effervescence in warm hydrochloric acid.

Obs.-Found in talcose schist, serpentine, and other magnesian rocks; as veins in serpenxine, or mixed with it so as to form a variety of verd-antique marble (magnesitic wphiolite of

Bunt); also in Canada, as a rock, more or less pure, associated with steatite, serpentine, and dolomite.
Occurs at Hrubschütz in Moravia ; in Styria, and in the Tyrol; at Frankenstein in Silesia; Snarum, Norway ; Baudissero and Castellamonte in Piedmont. In America, at Bolton, Mass.; at Barehills, near Baltimore, Md. ; in Penn., at West Goshen, Chester Co. ; near Texas, Lan• caster Co. ; California.

Mesitite and Pistomesite come under the general formula ( $\mathrm{Mg}, \mathrm{Fe}$ ) $\mathrm{CO}_{3}$; with the former $\mathrm{Mg}: \mathrm{Fe}=2: 1$; with the latter=1:1.

## SIDERITE. Spathic Iron. Chalybite. Eisenspath, Germ.

Rhombohedral. $R \wedge R=107^{\circ}, O \wedge R=136^{\circ} 37^{\prime} ; \dot{c}=0.81715$. The faces often curved, as below. Cleavage: rhombohedral, perfect. Twins : twinning-plane $-\frac{1}{2}$. Also in botryoidal and globular forms, subfibrous within, occasionally silky fibrous. Often cleavable massive, with cleavage planes undulating. Coarse or fine granular.
H. $=3 \cdot 5-4 \cdot 5 . \quad$ G. $=3 \cdot 7-3 \cdot 9 . \quad$ Lustre vitreous, more or less pearly. Streak white. Color ashgray, yellowish-gray, greenish-gray, also brown and brownish-red, rarely green ; and sometimes white. Translucent-subtranslucent. Fracture

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 uneven. Brittle.

Comp., $\boldsymbol{\nabla}$ ar.-Iron carbonate, $\mathrm{FeCO}_{3}=$ Carbon dioxide $37 \cdot 9$, iron protoxide $62 \cdot 1$. But part of the iron usually replaced by manganese, and often by magnesium or calcium. Some varieties contain 8-10 p. c. MnO.

The principal varieties are the following:
(1) Ordinary. (a) Crystallized. (b) Concretionary=Spherosiderite ; in globular concretions, either solid or concentric scaly, with usually a fibrous structure. (c) Granular to compact mas. sive. (d) Oölitic, like oölitic limestone in structure. (e) Earthy, or stony, impure from mixture with clay or sand, constituting a large part of the clay iron-stone of the coal formation and other stratified deposits ; $\mathrm{H} .=3$ to 7 , the last from the silica present; G. $=3 \cdot 0-3 \cdot 8$, or mostly $3 \cdot 15-3 \cdot 65$.

Pyr., eto.-In the closed tube decrepitates, evolves carbon oxide and carbon dioxide, blackens and becomes magnetic. B.B. blackens and fuses at 4.5 . With the fluxes reacts for iron, and with soda and nitre on platinum foil generally gives a manganese reaction. Only slowly acted upon by cold acid, but dissolves with brisk effervescence in hot hydrochloric acid.

Diff.-Specific gravity higher than that of calcite and dolomite. B. B. becomes magnetic readily.

Obs.-Siderite occurs in many of the rock strata, in gneiss, mica slate, clay slate, and as clay iron-stone in connection with the Coal formation and many other stratified deposits. It is often associated with metallic ores. At Freiberg it occurs in silver mines. In Cornwall it accompanies tin. It is also found accompanying copper and iron pyrites, galenite, vitreous copper, etc. In New York, according to Beck, it is almost always associated with specular iron. In the region in and about Styria and Carinthia this ore forms extensive tracts in gneiss. At Harzgerode in the Harz, it occurs in fine crystals; also in Cornwall, Alston-Moor, and Devonshire ; near Glasgow ; also at Mouillar, Magescote, etc., in France, etc.

In the U. States, in Vermont, at Plymouth. In Mass., at Sterling. In Conn., at Roxbury. In $N$. York, at the Sterling ore bed in Antwerp, Jefferson Co. ; at the Rossie iron mines, St. Lawrence Co. In N. Carolina, at Fentress and Harlem mines. The argillaceous carbonate, in nodules and beds (clay iron-stone), is abundant in the coal regions of Penn., Ohio, and many parts of the country.

RHODOCHROSITE.* Dialogite. Manganspath, Germ.
Rhombohedral. $R \wedge R=106^{\circ} 51^{\prime}, O \wedge R=136^{\circ} 31 \frac{1}{2}^{\prime} ; \quad \dot{c}=\mathrm{r} \cdot 8211$. Cleavage : $R$, perfect. Also globular and botryoidal, having a columnas structure, sometimes indistinct. Also granular massive; occasionally im palpable; iucrusting.
$\mathrm{H} . \dot{=} 3 \cdot 5-4 \cdot 5 . \quad \mathrm{G} .=3 \cdot 4-3 \cdot 7 . \quad$ Lustre vitreous, inclining to pearly. Color shades of rose-red, yellowish-gray, fawn-colored, dark red, brown. Streak white. Translucent-subtranslucent. Fracture uneven. Brittle.

[^50]SMITHSONITE. Calamine pt. Galmei pt. Zinkspath, Germ.
Rhombohedral. $R \wedge R=107^{\circ} 40^{\prime}, O \wedge R=137^{\circ} 3^{\prime} ; \dot{c}=0.8062 . \quad R$ generally curved and rough. Cleavage : $R$ perfect. Also reniform, botryoidal, or stalactitic, and in crystalline incrustations; also granular, and sometimes impalpable, occasionally earthy and friable.
$\mathrm{H} .=5$. G. $=4-4 \cdot 45$. Lustre vitreous, inclining to pearly. Streak white. Color white, often grayish, greenish, brownish-white, sometimes green and brown. Subtransparent-translucent. Fracture uneven-imperfectly conchoidal. Brittle.

Comp., Var.- $\mathrm{ZnCO}_{3}=$ Carbon dioxide $35 \cdot 2$, zinc oxide $64.8=100$; but part of the zinc often replaced by iron or manganese, and by traces of calcium and magnesium; sometimes by cadmium.

Varieties.-(1) Ordinary. ( (t) Crystallized; (b) botryoidal and stalactitic, common; (c) granular to compact massive; (d) earthy, impure, in nodular and cavernous masses, varying from grayish-white to dark gray, brown, brownish-red, brownish-black, and often with drusy surfaces in the cavities; "dry-bone" of American miners.

Pyr., etc.-In the closed tube loses carbon dioxide, and, if pure, is yellow while hot and colorless on cooling. B.B. infusible; moistened with cobalt solution and heated in O.F. gives a green color on cooling. With soda on charcoal gives zinc vapors, and coats the coal yellow while hot, becoming white on cooling ; this coating, moistened with cobalt solution, gives a green color after heating in O.F. Cadmiferous varieties, when treated with soda, give at first a deep yellow or brown coating before the zinc coating appears. With the fluxes some varieties react for iron, copper, and manganese. Soluble in hydrochloric acid with effervescence.

Diff.-Distinguished from calamine by its effervescence in acids.
Obs.-Smithsonite is found both in veins and beds, especially in company with galenite and blende; also with copper and iron ores. It usually occurs in calcareous rocks, and is generally associated with calamine, and sometimes with limonite. It is often produced by the actinu of zinc sulphate upon calcium or magnesium carbonate.

Found at Nertschinsk in Siberia ; at Dognatzka in Hungary; Bleiberg and Raibel in Carinthia; Moresnet in Belgium. In England, at Roughten Gill, Alston Moor, near Matlock, in the Mendip Hills, and elsewhere ; in Scotland, at Leadhills; in Ireland, at Donegal.

In the U. States, in N. Jersey, at Mine Hill, near the Franklin Furnace. In Penn., at Lancaster abundant; at the Perkiomen lead mine; at the Ueberroth mine, near Bethlehem. In Wisconsin, at Mineral Point, Shullsburg, etc. In Minnesota, at Ewing's diggings, N. W. of Dubuque, etc. In Missouri and Arkansas, along with the lead ores in Lower Silurian limestone.

## Aragonite Group.

## ARAGONITE.

Orthorhombic $I \wedge I=116^{\circ} 10^{\prime}, O \wedge 1-\bar{\imath}=130^{\circ} 50^{\prime} ; \dot{c}: \bar{b}: \breve{a}=1 \cdot 1571$ $: 1.6055: 1$. $O \wedge 1=126^{\circ} 15^{\prime}, O \wedge 1-\Sigma=137^{\circ} 15^{\prime}, 1-\check{ } \wedge 1-\check{\varkappa}$, top $:=108^{\circ}$ $26^{\prime}$. Crystals usnally having $O$ striated parallel to the shorter diagonal; often tapering from the presence of acute domes and pyramids, which have unusual indices. Cleavage: $I$ imperfect; $i-乞$ distinct; $1-\check{\imath}$ imperfect. Twins: twinning-plane 1 , producing often hexagonal forms, f. 738, compare figures on pp. 96, 97. Twinning often many times repeated in the same crystal, producing successive reversed layers, the alternate of which may be exceedingly thin; often so delicate as to produce by the succession a fine striation of the faces of a prism or of a cleavage plane. Also globular, reniform, and coralloidal shapes; sometimes columnar, composed of itraight and divergent fibres; also stalactitic ; incrusting.

H. $=3 \cdot 5-4$. G. $=2 \cdot 931$, Haidinger. Lustre vitreons, sometimes inclining to resinous on surfaces of fracture. Color white; also gray, yellow, green, and violet ; streak uncolored. Transparent-translucent. Fracture subconchoidal. Brittle.

[^51]at Leogang in Salzburg; in Waltsch, Bohemia, and many other places. The ADoferri variety is found in great perfection in the Styrian mines. In Buckinghamshire, Devonshire, in caverns; at Leadhills in Lanarkshire.

Occurs in serpentine at Hoboken, N. J.; at Edenville, N. Y.; at the Parish ore bed, Rossie, N. Y.; at Haddam, Conn.; at New Garden, in Chester Co., Penn.; at Wood's Mine, Lancaster Co., Penn.; at Warsaw, Ill., lining geodes.

Manganocalcite. - Composition $2 \mathrm{MnCO}_{3}+(\mathrm{Ca}, \mathrm{Mg}) \mathrm{CO}_{3}$, with a little iron replacing part of the manganese. G. $=3 \cdot 037$. Color flesh-red to reddish-white. Schemnitz, Hungary.

## WITHERITE.

Orthorhombic. $\quad I \wedge I=118^{\circ} 30^{\prime}, O \wedge 1-\bar{\imath}=128^{\circ} 45^{\prime} ; \dot{c}: \bar{b}: \breve{a}=1 \cdot 246$ : $1 \cdot 6808: 1$. Twins : all the annexed figures, composition parallel to $I$; reëntering angles sometimes observed. Cleavage: $I$ distinct; also in globular, tuberose, and botryoidal forms; structure either columnar or granular ; also amorphous.
$\mathrm{H} .=3-3 \cdot 75 . \quad \mathrm{G} .=4 \cdot 29-4 \cdot 35$. Lustre vitreous, inclining to resinous, on surfaces of fracture. Color white, often yellowish, or grayish. Streak white. Subtransparent-translucent. Fracture uneven. Brittle.

Comp. $-\mathrm{BaCO}_{3}=$ Carbon dioxide $22 \cdot 3$, baryta $77 \cdot 7=100$.
Pyr., etc.-B.B. fuses at 2 to a bead, coloring the flame yel-lowish-green; after fusion reacts alkaline. B.B. on charcoal with soda fuses easily, and is absorbed by the coal. Soluble in dilute hydrochloric acid; this solution, even when very much diluted, gives with sulphuric acid a white precipitate which is insoluble in acids.
Diff.-Distinguishing characters: high specific gravity; effervescence with acids; green coloration of the flame B.B.
Obs.-Occurs at Alston-Moor in Cumberland; at Fallowfield, near Hexham in Northumberland; Tarnowitz in Silesia; Leogang in Salzburg ; Peggau in Styria ; some places in Sicily ; the mine of Arqueros, near Coquimbo, Chili; near Lexington, Ky., with barite.
Witherite is extensively mined at Fallowfield, and is used in chemical works in the manufacture of plate-glass, and in France in making beet-sugar.
Bromlite.-Formula as for barytocalcite, but orthorhombic in form.

## STRONTIANITE.

Orthorhombic. $I \wedge I=117^{\circ} 19^{\prime}, O \wedge 1-\bar{\imath}=130^{\circ} 5^{\prime} ; \dot{c}: \bar{b}: \breve{a}=1 \cdot 1883$ : $1 \cdot 6421$ : $1 . \quad O \wedge 1=125^{\circ} 43^{\prime}, O \wedge 1-\check{\imath}=144^{\circ} 6$,

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 $1 \wedge 1$, mac., $=130^{\circ} 1^{\prime}, 1 \wedge 1$, brach., $=92^{\circ} 11^{\prime}$. Cleavage: I nearly perfect, $i-\imath$ in traces. Crystals often acicular and in divergent groups. Twins: like those of aragonite. O usually striated parallel to the shorter diagonal. Also in columnar globular forms; fibrous and gramular. $H .=3 \cdot 5-4 . \quad$ G. $=3 \cdot 605-3 \cdot 713$. Lustre vitreous; inclining to resinous on uneven faces of fracture. Color pale asparagus-green, apple-green; also white, gray, yellow, and yellowish-brown. Streak white. Transparent-translucent. Fracture uneven. Brittle.

Comp.- $\mathrm{SrCO}_{3}=$ Carbon diuxide 297 , strontia 70.3 ; but a small part of the strontium often replaced by calcium.

Pyr., etc.-B.B. swells up, throws out minute sprouts, fuses only on the thin edges, and colors the flame strontia-red; the assay reacts alkaline after Ignition. Moistened with hydrochloric acid and treated either B.B. or in the naked lamp gives an intense red color. With soda on charcoal the pure mineral fuses to a clear glass, and is entirely absorbed by the coal ; if lime or iron be present they are separated and remain on the surface of the coal. Soluble in hydrochloric acid; the dilute solution when treated with sulphuric acid gives a white precipitate.

Diff.-Differs from related minerals, not carbonates, in effervescing with acids; lower specific gravity than witherite, and colors the flame red.

Obs.-Occurs at Strontian in Argyleshire; in Yorkshire, England; Giant's Causeway, Ireland; Clausthal in the Harz; Bräunsdorf, Saxony; Leogang in Salzburg. In the U. States it occurs at Schoharie, N. Y., in granular and columnar masses, and also in crystals. At Muscalonge Lake; at Chaumont Bay and Theresa, in Jefferson Co., N. Y. ; Mifflin Co., Penn

CERUSSITE. Weissbleierz, Bleispath, Germ.
Orthorhombic. $I \wedge I=117^{\circ} 13^{\prime}, O \wedge 1 \cdot \bar{\imath}=130^{\circ} 9 \frac{1^{\prime}}{} ; ~ c \quad: \bar{b}: \breve{u}=1 \cdot 1852$ : $1 \cdot 6383: 1 . \quad O \wedge 1=125^{\circ}$ $46^{\prime}, ~ O \wedge 1-\check{\imath}=145^{\circ} 8^{\prime}, 1 \wedge 1$, mac., $=130^{\circ}, 1 \wedge 1$, brach., $=$ $92^{\circ} 19^{\prime}$. Cleavage: $I$ often imperfect ; $2-\check{\imath}$ hardly less so. Crystals usually thin, broad, and brittle; sometimes stont. Twins: very common; twin-ning-plane $I$, producing usually cruciform or stellate forms; also less commonly, twinning-plane $i-3$. Rarely fibrous, often granular mas-
 sive and compact. Sometimes stalactitic.
H. $=3-3 \cdot 5$. G. $=6 \cdot 465-6 \cdot 480$; some earthy varieties as low as $5 \cdot 4$. Lustre adamantine, inclining to vitreous or resinous; sometimes pearly; sometimes submetallic, if the colors are dark, or from a superficial change. Color white, gray, grayish-black, sometimes tinged blue or green by some of the salts of copper; streak uncolored. Transparent-subtranslucent. Fracture conchoidal. Very brittle.

Comp. $-\mathrm{PbCO}_{3}=$ Carbon dioxide $16 \cdot 5$, lead oxide $83 \cdot 5=100$.
Pyr., etc. - In the closed tube decrepitates, loses carbon dioxide, turns first yellow, and at a higher temperature dark red, but becomes yellow again on cooling. B. B. on charcoal fuses very easily, and in R.F. yields metallic lead. Soluble in dilute nitric acid with effervescence.

Diff.-Unlike anglesite, it effervesces with nitric acid. Characterized by high specific gravity, and yielding lead B.B.

Obs.-Occurs in connection with other lead minerals, and is formed from galenite, which, as it passes to a sulphate, may be changed to carbonate by means of solutions of calcium bicarbonate. It is found at Johanngeorgenstadt; at Nertschinsk and Beresof in Siberia; at Clausthal in the Harz; at Bleiberg in Carinthia; at Mies and Przibram in Bohemia; at Retzbanya, Hungary; in England, in Cornwall; near Matlock and Wirksworth, Derbyshire; at Leadhills, Scotland ; in Wicklow, Ireland.

Found in Penn., at Phenixville ; at Perkiomen. In N. York, at the Rossie lead mine. In I'irginia, at Austin's mines, Wythe Co. In N. Carolina, at King's mine, Davidson Co., good. In Wisconsin and other lead mines of the northwestern States, rarelv in crystals; near the Blue Mounds, Wisc., in stalactites.

## BARYTOCALCITE.

Monoclinic. $C=73^{\circ} 52^{\prime}, I \wedge I=106^{\circ} 54^{\prime}, O \wedge 1-\grave{\imath}=149^{\prime} ; \dot{c}: \bar{b}: \dot{a}=$ $0.81035: 1.29583: 1$. Cleavage: $I$, perfect; $O$, less perfect; also massive. H. $=4$. G. $=3 \cdot 6363-3 \cdot 66$. Lustre vitreons, inclining to resinous. Color white, grayish, greenish, or yellowish. Streak white. Transparenttranslucent. Fracture uneven.

Comp.- $(\mathrm{Ba}, \mathrm{Ca}) \mathrm{CO}_{3}$, where $\mathrm{Ba}: \mathrm{Ca}=1: 1=$ Barium carbonate $66 \cdot 3$, calcium carbonate $33 \cdot 7=100$.

Pyr., etc.-B.B. colors the flame jellowish-green, and at a higher temperature fuses or the thin edges and assumes a pale green color ; the assay reacts alkaline after ignition. With the fluxes reacts for manganese. With soda on charcoal the lime is separated as an infusible mass, while the remainder is absorbed by the coal. Soluble in dilute hydrochloric acid.

Obs.-Occurs at Alston-Moor in Cumberland, in the Subcarboniferous or mountain limestone.

Parisite.-A carbonate containing cerium (also La, Di), and calcium with 6 p. c. fluorine. Exact composition uncertain. In hexagonal crystals. Color brownish-yellow. Muso valley, New Granada. Kiscititimite, from the gold washing of the Barsovska river, Urals, is similar in composition, but contains no calcium.

Bastnäsite (Hamartite).-Composition $2 \mathrm{RCO}_{3}+\mathrm{RF}_{2}$, with $\mathrm{R}=\mathrm{Ce}: \mathrm{La}=2: 3$. Analysis, Nordenskiöld, $\mathrm{CO}_{2} 19 \cdot 50$, LaO $45 \cdot 7 \%$, $\mathrm{CeO} 28 \cdot 49, \mathrm{H}_{2} \mathrm{O} 1 \cdot 01, \mathrm{~F}, \mathrm{O},(5 \cdot 23)=100$. Found in small masses imbedded between allanite crystals. Riddarhyttan, Sweden.

PHOSGENITE. Bleihornerz, Germ.
Tetragonal. $O \wedge 1-i=132^{\circ} 37^{\prime} ; \dot{c}=1 \cdot 0871$. Cleavage: $I$ and $i-i$ bright ; also basal.
H. $=2.75-3$. G. $=6-6 \cdot 31$. Lustre adamantine. Color white, gray, and yellow. Streak white Transparent-translucent. Rather sectile.

Comp. $-\mathrm{PbCO}_{3}+\mathrm{PbCl}_{2}=$ Lead carbonate 49 , lead chloride $51=100$, or lead oxide $81 \cdot 9$, carbon dioxide $8 \cdot 1$, chlorine $13 \cdot 0=102 \cdot 9$.

Pyr., etc.-B.B. melts readily to a yellow globule, which on cooling becomes white and crystalline. On charcoal in R.F. gives metallic lead, with a white coating of lead chloride. With a salt of phosphorus bead previously saturated with copper oxide gives the chlorine reaction. Dissolves with effervescence in nitric acid.

Obs.-At Cromford near Matlock in Derbyshire ; very rare in Cornwall; in large crystals at Gibbas and Monteponi in Sardinia; near Bobrek in Upper Silesia.

## Hydrous Carbonatks.

## TRONA.

Monoclinic. $O \wedge i-i=103^{\circ} 15^{\prime}$. Cleavage: $i-i$ perfect. Often fibrous or columnar massive.
$\mathrm{H} .=2 \cdot 5-3$. G. $=2 \cdot 11$. Lustre vitreans, glistening. Color gray or yel-lowish-white. Translucent. Taste alkaline. Not altered by exposure to a dry atmosphere.
Comp. $-\mathrm{Na}_{4} \mathrm{C}_{3} \mathrm{O}_{8}+3 \mathrm{aq}=$ Carbon dioxide $40 \cdot 2$, soda $37 \cdot 8$, water $22 \cdot 0$.
Pyr., etc.-In the closed tube yields water and carbon dioxide. B.B. imparts an intensely yellow color to the flame. Soluble in water, and effervesces with acids. Reacts alkaline with moistened test paper.

Obs.-The specimen analyzed by Klaproth came from the province of Suckenna, two days' journey from Fezzen, ica. To this species belongs the urao fcund at the bottom of a lake

In Maracaibo, S. A., a day's journey from Merida. Efflorescences of trona occur near the Sweetwater river, Rocky Mountains, mixed with sodium sulphate and sommon salt.

Natron or Soda (sodium carbonate, $\mathrm{Na}_{2} \mathrm{CO}_{3}+10 \mathrm{aq}$ ). Thermonatrite, $\mathrm{Na}_{2} \mathrm{CO}_{3}+\mathrm{aq}$. Teschemacherite, Ammonium carbonate.

## GAY-LUSSITE.

Monoclinic. $C^{\gamma}=78^{\circ} 27^{\prime}, I \wedge I=68^{\circ} 50^{\prime}$ and $111^{\circ} 10^{\prime}, O \wedge 1-\grave{\imath}=125^{\circ}$ $15^{\prime} ; \dot{c}: b: \grave{a}=0.96945: 0.67137: 1$. $1-\grave{\imath} \wedge 1-\grave{\imath}$, adj., $=109^{\circ} 30^{\prime}$, $\frac{1}{2} \wedge \frac{1}{2}=110^{\circ}$ $30^{\prime}$. Crystals often lengthened, and prismatic in the direction of $1-\grave{\imath}$; also in that of $\frac{1}{2}$; also (fr. Nevada) not elongate, but thin in the direction of the orthodiagonal, $O$ being very narrow or wanting; surfaces usually uneven, being formed of minute subordinate planes. Cleavage : $I$ perfect; $O$ less so, but giving a reflected image in a strong light.


Maracaibo.


Nevada.
H. $=2-3 . \quad$ G. $=1.92-1.99$. Lnstre vitreous. Color white, yellowishwhite. Streak uncolored to grayish. Translucent. Fracture conchoidal. Extremely brittlc. Not phosphorescent by friction or heat.

Comp. $-\mathrm{Na}_{2} \mathrm{CO}_{3}+\mathrm{CaCO}_{3}+5 \mathrm{aq}=$ Sodium carbonate $35 \cdot 9$, calcium carbonate $33 \cdot 8$, water $30 \cdot 3=100$.

Pyr., etc.-Heated in a matrass the crystals decrepitate and become opaque. B.B. fuses easily to a white enamel, and colors the flame intensely yellow. With the fluxes it behaves like calcium carkonate. Dissolves in acids with a brisk effervescence ; partly soluble in water, and reddens turmeric.

Obs.-Abundant at Lagunilla, near Merida, in Maracaibo, where its crystals are disseminated at the bottom of a small lake, in a bed of clay, covering urao; the natives call it clavos or nails, in allusion to its crystalline form. Also on a small island in Little Salt Lake, near Ragtown, Nevada, about $1 \frac{1}{2} \mathrm{~m}$. S. of the main emigrant road to Humboldt. The lake is in a crater-shaped basin, and its waters are dense and strongly saline.

The distorted crystals from Sangerhausen have been long considered pseudomorphs after gay-lussite, though Des Cloizeaux regards them as pseudomorphs after celestite. Groth regards them as perhaps pseudomorphs after anhydrite. See also thinolite, p. 438.

## HYDROMAGNESITE.

Monoclinic. $C=82^{\circ}-83^{\circ}, I \wedge I=87^{\circ} 52^{\prime}-88^{\circ}, O \wedge 2-\grave{\imath}=137^{\circ} ; \dot{c}: b$ $: \grave{a}=$ (nearly) $0 \cdot 455: 1 \cdot 0973: 1$. Crystals small, usually scicular or bladed, and tufted. Also amorphous; as chalky or mealy crusts.
H. of crystals $3 \cdot 5$. G. $=2 \cdot 145-2 \cdot 18$, Smith \& Brush. Lustre vitreous to silky or subpearly; also earthy. Color and streak white. Brittle.

Comp. $-3 \mathrm{MgCO}_{3}+\mathrm{H}_{2} \mathrm{MgO}_{2}+3 \mathrm{aq}=$ Carbon dioxide $36 \cdot 3$, magnesia $43 \cdot 9$, water $19 \cdot \delta=100$.

Pyr., etc.-In the closed tube gives off water and carbon dioxide. B.B. infusible, but whitens, and the assay reacts alkaline to turneric paper. Soluble in acids; the crystalline compact varieties are but slowly acted upon by cold acid, but dissolves with effervescence in hot acid.


Obs.-Occurs at Hrubschitz, in Moravia, in serpentine; in Negroponte, near Kumi ; at Kaiserstuhl, in Baden, impure. In the U. States, near Texas, Lancaster Co., Penn.; at Hoboken, N. J.

Hydrodolomite.-Composition $3(\mathrm{Ca} . \mathrm{Mg}) \mathrm{CO}_{3}+$ aq. From Mt Somma. Pennite from Texas, Pa., is similar.

Predazzite and Pencatite are mixtures of calcite and brucite. Tyrol.
Dawsonite.-In thin-bladed, white, transparent crystals on trachyte. H. $=3$. G. $=2 \cdot 40$. Analysis, Harrington, $\mathrm{HlO}_{3} 32 \cdot 84, \mathrm{MgO}$ tr., $\mathrm{CaO} 5.95, \mathrm{Na}_{2} \mathrm{O} 20 \cdot 20, \mathrm{~K}_{2} \mathrm{O} 0.38, \mathrm{H}_{2} \mathrm{O} 11.91, \mathrm{CO}_{2}$ $29.88, \mathrm{SiO}_{2} 0 \cdot 40=101.56$. Regarded as "a hydrous carbonate of aluminum, calcium, and sodium ; or perhaps as a hydrate of aluminum with carbonates of calcium and sodium." Montreal, Canada.

Hovite.-Supposed to be a hydrous carbonate of aluminum and calcium. Soft, white, and friable; earthy in fracture. From Hove, near Brighton, with collyrite.

## LANTHANITE.

Orthorhombic. $I \wedge I=93^{\circ} 30^{\prime}-94^{\circ}$, Blake, $92^{\circ} 46^{\prime}$, v. Lang ; $I \wedge 1=$ $142^{\circ} 36^{\prime} ; \dot{c}: \bar{b}: \breve{a}=0.99898: 1.0496: 1$, v. Lang. In thin four-sided plates or minute tables, with bevelled edges. Cleavage micaceous. Also fine granular or earthy.
$\mathrm{H} .=2 \cdot 5-3 . \quad \mathrm{G} .=2 \cdot 666 . \quad$ Lustre pearly or dull. Color grayish-white, delicate pink, or yellowish.

Comp. $-\mathrm{LaCO}_{3}+3 \mathrm{aq}=$ Lanthana $52 \cdot 6$, carbon dioxide $21 \cdot 3$, water $26 \cdot 1=100$. There is some oxide of didymium with the lanthana, according to Smith.

Pyr., etc.-In the closed tube yields water. B.B. infusible; but whitens and becomes opaque, silvery, and brownish ; with borax, a glass, slightly bluish, reddish, or amethystine, on cooling; with salt of phosphorus a glass, bluish amethystine while hot, red cold, the bead becoming opaque when but slightly beated, and retaining a pink color. Effervesces in the acids.

Obs.-Found coating cerite at Bastnäs, Sweden; also with the zinc ores of the Saucon valley, Lehigh Co., Pa.; at the Sandford iren-ore bed, Moriah, Essex Co., N. Y.

Tengerite.-Yttrium carbonate. As a a ating on gadolinite from Ytterby.
Zaratite. Emerald Nickel, Silliman. Nickelsmaragd, Germ. - Composition $\mathrm{Ni}_{3} \mathrm{CO}_{5}+$ 6 aq , or $\mathrm{NiCO}_{3}+2 \mathrm{H}_{2} \mathrm{NiO}_{2}+4 \mathrm{aq}$. This requires: Carbon dioxide $11 \cdot 8$, nickel oxide $59 \cdot 3$, water $28 \cdot 9=100$. Usually as an emerald-green coating; thus on chromite at Texas, Penn., where it was first noticed; Swinaness, Shetland; Cape Ortegal, Spain.
Reming ronite.-A hydrous cobalt carbonate. Finksburg, Md.

## HYDROZINCITE. Zinkblüthe, Germ.

Massive, earthy or compact. As incrustations, the crusts sometimes concentric and agate-like. At times reniform, pisolitic, stalactitic.
$\mathrm{H} .=2-2 \cdot 5$. G. $=3 \cdot 58-3 \cdot 8$. Lustre dull. Color pure white, grayish or yellowish. Streak shining. Usually earthy or chalk-like.

Comp.-In part $\mathrm{ZnCO}_{3}+2 \mathrm{H}_{2} \mathrm{ZnO}_{3}=$ Carbon dioxide $13 \cdot 6$, zinc oxide $75 \cdot 3$, water $11 \cdot 1=100$.
Pyr., etc.-In the closed tube yields water ; in other respects resembles smithsonite.
Obs.-Occurs at most mines of zinc, and is a result of the alteration of the other ores of this metal. Found in great quantities at the Dolores mine. Udias valley, province of Santander, in Spain; at Bleiberg and Raibel in Carinthia; near Reimsbeck, in Westphalia

In the U. States, at Friedensville, Pa.; at Linden, in Wisconsin; in Marion Co., Arkansas (marionite).
AURICHALCITE.-A cupreous hydrozincite. Usually in drusy incrustations. Altai;
Matlock, Derbyshire; Spain ; Lancaster, Pa.

## MALACHITE.

Monoclinic. $C=88^{\circ} 32^{\prime}, I \wedge I=104^{\circ} 28^{\prime}, i-i \wedge-1-i=118^{\circ} 15^{\prime}$, Zepharo vich; $\dot{c}: b: \dot{u}=0.51155: 1 \cdot 2903: 1$. Common form f. 750 ; also same with other terminal planes; also with $i-i$ wanting; also with $i-i$, $i-\grave{\imath}$ very large, making a rectangular prisin; also with the vertical prism very short, as in f. 321. Crystals rarely simple. Twins: twinningplane $i-i, \mathrm{f} .750$; often penetration twins, as in f. 321, 322, p. 99. Cleavage : basal, highly perfect; clinodiagonal less distinct. Usually massive or incrusting, with surface tuberose, botryoidal, or stalactitic, and structure divergent; often delicately compact fibrous, and banded in color; frequently granular or earthy.
H. $=3 \cdot 5-4$. G. $=3 \cdot 7-4 \cdot 01$. Lustre of crystals adaman-

750
 tine, inclining to vitreous; of fibrous varieties more or less silky; often dull and earthy. Color bright green. Streak paler green. Translucent-subtranslucent-opaque. Fracture subconchoidal, uneven.

Comp.- $\mathrm{Cu}_{2} \mathrm{CO}_{4}+\mathrm{H}_{2} \mathrm{O}=\mathrm{CuCO}_{3}+\mathrm{H}_{2} \mathrm{CuO}_{2}=$ Carbon dioxide $19 \cdot 9$, copper oxide $71 \cdot 9$, water $R \cdot 2=100$.

Pyr., etc.-In the closed tube blackens and yields water. B.B. fuses at 2, coloring the flame emerald-green; on charcoal is reduced to metallic copper; with the fluxes reacts like tenorite. Soluble in acids with effervescence.

Diff.-Differs from other copper ores of a green color in its effervescence with acids.
Obs.-Green malachite accompanies other ores of copper. Perfect crystals are quite rare. Occurs abundantly in the Urals; at Chessy in France; at Schwatz in the Tyrol; in Cornwall and in Cumberland, England; Sandlodge copper mine, Scotland; Limerick, Waterford. and elsewhere, Ireland; at Grimberg, near Siegen in Germany. At the copper mines of NischneTagilsk, belonging to M. Demidoff, a bed of malachite was opened which yielded many tons of malachite. Also in handsome masses at Bembe, on the west coast of Africa; with the copper ores of Cuba; Chili ; Australia.

In N. Jersey, at New Brunswick. In l'ennsylvania, near Morgantown, Berks County ; at Cornwall, Lebanon Co. ; at the Perkiomen and Phenixville lead mines. In Wisconsin, at the copper mines of Mineral Point, and elswhere. In California, at Hughes's mine in Calaveras Co.

Green malachite admits of a high polish, and when in large masses is cut into tables, snuffboxes, vases, etc. Named from $\mu a \lambda a \chi$ 向, mallows, in allusion to the green color.

Cuprocalcite.-Massive. $H=3 . \quad$ G. $=3.90$. Color vermilion-red. Analysis, Raymondi, $\mathrm{Cu}_{2} \mathrm{O} 50.45, \mathrm{CaO} 20 \cdot 16, \mathrm{CO}_{2} 24 \cdot 00, \mathrm{H}_{2} \mathrm{O} 3 \cdot 20, \mathrm{FeO}_{3} 0 \cdot 60, \mathrm{AlO}_{3} 0 \cdot 20, \mathrm{MgO} 0 \cdot 97, \mathrm{SiO}_{2} 0 \cdot 30=$ $99 \cdot 86$. Occurs with a ferruginous calcite at the copper mines of Canza in Pera.

## AZURITE. Kupferlasur, Germ.

Monoclinic. $C=87^{\circ} 39^{\prime} ; I \wedge I=99^{\circ} 32^{\prime}, O \wedge 1-\grave{\imath}=138^{\circ} 41^{\prime} ; c: b: a$ $=1.039: 1 \cdot 181: 1$. $O$ usually $\begin{gathered}\text { etriated parallel with the clinodiagonal. }\end{gathered}$ Cleavage: $2-i$ rather perfect; $i-i$ less distinct; $I$ in traces. Also massive, and presenting imitative shapes, having a columnar composition ; also dull and earthy.
H. $=3 \cdot 5-4 \cdot 25 . \quad \mathrm{G} .=3 \cdot 5-3 \cdot 831$. Lustre vitreous, almost adamantine. Color various shades of azure-blue, passing into Berlin-blue. Streak blue, lighter than the color. Transparent-subtranslucent. Fracture conchoidal. Brittle.

Comp. - $\mathrm{Cu}_{3} \mathrm{C}_{2} \mathrm{O}_{7}+\mathrm{H}_{2} \mathrm{O}=2 \mathrm{CuCO}_{3}+\mathrm{H}_{2} \mathrm{CuO}_{2}=$ Carbon dioxide $25 \cdot 6$, copper oxide $69 \cdot 2$, water $5 \cdot 2=100$.

Pyr., etc.-Same as in malachite.
Obs.-Occurs at Chessy, near Lyons, whence its name Chessy Copper. Also in Siberia; at Moldava in the Banat ; at Wheal Buller, near Redruth in Cornwall - also in Devonshire and Derbyshire.

In Penn., at the Perkiomen lead mine; at Phenixville, in crystals; at Cornwall. In Wis consin, near Mineral Point In California, Calaveras Co., at Hughes's mine.

According to Schrauf, who has given a crystallographic monograph of the species, the form is closely related to that of epidote (Ber. Ak. Wien, July 3, 1871).

## BISMUTITE. Wismuthspath, Germ.

In implanted acicular crystallizations (pseudomorphous) ; also incrusting or amorphous; pulverulent.
H. $=4-4.5$. G. $=6 \cdot 86-6.909$. Lustre vitreous, when pure; sometimes dull. Color white, mountain-green, and dirty siskin-green; occasionally straw-yellow and yellowish-gray. Streak greenish-gray to colorless. Sub-translucent-opaque. Brittle.

Comp.-2 $\mathrm{Bi}_{8} \mathrm{C}_{3} \mathrm{O}_{18}+9 \mathrm{H}_{2} \mathrm{O}$, Ramm. (S. Carolina)=Carbon dioxide 6.38 , bismuth oxide $89 \cdot 75$, water $3 \cdot 87=100$.
Pyr., etc.-In the closed tube decrepitates and gives off water. B.B. fnses readily, and on charcoal is reduced to bismuth, and coats the coal with yellow bismuth oxide. Dissolves in nitric acid, with slight effervescence. Dissolves in hydrochloric acid, affording a deep yellow solution.

Obs.-Bismutite occurs at Schneeberg and Johanngeorgenstadt; at Joachimsthal ; near Baden ; also in the gold district of Chesterfield, S. C. ; in Gaston Co., N. C., in yellowishwhite concretions.

Liebigite; Voglite (Urankalk, Germ.).-Carbonates of uranium and calcium, from the decomposition of uraninite. Exact composition doubtful. SCHRÖckingerite is an oxycarbonate of urauium (Schrauf). Orthorhombic. Occurs in six-sided tabular crystals. Joachimsthal.

Whewellite. - An oxalate of calcium. In minute monoclinic crystals on calcite.
Humboldtite.-A hydrous oxalate of iron, $2 \mathrm{FeC}_{2} \mathrm{O}_{4}+3 \mathrm{aq}$. Compact; earthy. In browncoal of Koloseruk, near Bilin; also in black shales at Kettle Point; in Bosanquet, Canada.
Mellite (Honigstein, Germ.).-Tetragonal. In octahedrons; also massive, honey-yellow, reddish, or brownish, rarely white. Al $\mathrm{C}_{12} \mathrm{O}_{12}+18 \mathrm{aq}=$ Alumina 14.36 , mellitic acid $40 \cdot 30$, water $45.34=10^{\prime}$ ). Artern, Thuringia; Luschitz, Bohemia; Walchow, Moravin; Nertschinsk, otc.

## VI. HYDROCARBON COMPOUNDS

The Hydrogen-Carbon Compounds include (1) the smiple irdrocarbons; and (2) the oxygenated hymrocarbons.

1. The simple hydro carbons embrace :
(a) The Marsh Gas serics. General formula $\mathrm{C}_{\mathrm{n}} \mathrm{H}_{2 \mathrm{n}+2^{\circ}}$. Here belong the liquid naphthas, the more volatile parts of petroleum; also the butter-like solids schecrerite and chrismatite.

Petroledm. - Mineral oil. Kerosene. Bergöl, Steinöl, Erdöl, Germ. Petroleum is a thick to thin fluid. Color yellow or brown, or colorless; translucent to transparent. The specific gravity varies from 0.7 to 0.9 . Chemically it consists essentially of carbon and hydrogen; containing several members of the naphtha group, as also the oils of the ethylene series, and the paraffins. The proportion of the latter constituents increases with the increase of the density or viscidity of the fluid. It grades insensibly into pittasphalt, and that into solid bitumen.

Occurs in rocks or deposits of nearly all geological ages, from the Lower Silurian to the present epoch. It is associated most abundantly with argillaceous shales and sandstones, but is found also permeating limestones, giving them a bituminous odor, and rendering them sometimes a considerable source of oil. From these oliferous shales and limestones the oil often exudes, and appears floating on the streams or lakes of the region, or rises in oil springs. It also exists collected in subterranean cavities in certain rocks, whence it issues in jets or fountains whenever an outlet is made by boring. These cavities are situated mostly along the course of gentle anticlinals in the rocks of the region; and it is therefore probable, as has been suggested, that they originated for the most part in the displacements of the strata caused by the slight uplift. The oil which fills the cavities has ordinarily been derived from the subjacent rocks; for the strata, in which the cavities exist, are frequently barren sandstones.

Obtained in large quantities from the oil wells of Pennsylvania; also found in eastern Virginia, Kentucky, Ohio, Illinois, Michigan, and New York. In Canada, at several places; in southern California; in Mexico; Trinidad.
Some well-known foreign localities are: Rangoon, Burmah; western shore of the Caspian Sea; in Parma, Italy ; Sicily; Galicia; Tegernsee, Bavaria; Hanover.
(b) The Olefiant or Ethylene series. General formula $\mathrm{C}_{\mathrm{n}} \mathrm{H}_{2 \mathrm{n}}$. Here belong the pittolinm group of liquids, or pittasphalts (mineral tar'), and the parafins.

Paliaffin group.-Wax-like in consistence; white and translucent. Sparingly soluble in alcohol, rather easily in ether, and crystallizing more or less perfectly from the solutions. G. about $0.85-0.98$. Nelting point for the following species, $: 33^{\circ}-90^{\prime}$. The different species varying in the value of $n$, vary also in boiling point, and other characters.
Paraffins occur in the Pennsylvania petroleum, a freezing mixture reducing the temperature being sufficient to separate it in crystals. Also in the naphtha of the Caspian, in Rangoon tar, and many other liquid bitumens. It is a result of the destructive distillation of peat, bituminous coal, lignite, coaly or bituminous shales, most viscid bitumens, wood-tar, and many other substances.
The name is from the Latin parum, little, and affinis, alluding to the feeble affinity for other substances, or, in other words, its chemical indifference.

To the Paraffin Group belong:
Urpermite.-Consistency of soft tallow. Melting point $39^{\circ}$ C. Soluble in cold ether. Urpeth Collierv.

Hatchettite.-In thin plates or massive. Color yellowish, or greenish-white; blackens on exposure. Melting point $46^{\circ} \mathrm{C}$. In the coal-measures of Glamorganshire; Rossitz, Moravia.

Ozocerite.-Like wax or spermaceti in appearance and consistency. G. $=0.85-0.90$. Colorless to white when pure ; often leek-green, yellowish, brownish-yellow, brown. Trans lucent. Greasy to the touch. Fusing point $56^{\circ}$ to $63^{\circ} \mathrm{C}$. Occurs in beds of coal, or associated litumin Jus deposits ; that of Slanik, Moldavia, beneath a bed of bituminous clay shale; in masses of sometimes 80 to 100 lbs ., at the foot of the Carpathians, not far from beds of coal and salt; that of Boryslaw in a bituminous clay associated with calciferous beds in the formation of the Carpathians, in masses. The same compound has been obtained from mineral coal, peat, and petroleum, mineral tar, etc., by destructive distillation. Named from $\ddot{\partial} \zeta \omega$, smell, and кпрós, wax, in allusion to the odor.

Elaterite.-Massive, soft, elastic; often like india-rubber, though sometimes hard and brittle. It is found at Castleton in Derbyshire, in the lead mine of Odin, along with lead ore and calcite, in compact reniform or fungoid masses, and is abundant. Also reported from St. Bernard's Well, Edinburgh, etc.

Zietrisikite and Pyropissite belong here.

## (c) The Camphene Series. General Formula $\mathrm{C}_{\mathrm{n}} \mathrm{H}_{2 \mathrm{n}-4}$.

Fichtelitf. - In white monoclinic crystals. Brittle. Solidifies at $36^{\circ} \mathrm{C}$. Soluble in ether. The mineral occurs in the form of shining scales, flat crystals, and thin layers between the rings of growth and throughout the texture of pine wood (identical in species with the modern Pinus sylvestris) from peat beds in the vicinity of Redwitz in the Fichtelgebirge, North Bavaria. In peat near Sobeslau; in a $\log$ of Pinus Australis.

Hartite.-Resembles fichtelite, but melts at $74^{\circ}-75^{\circ} \mathrm{C}$. Found in a kind of pine, like fichtelite. but of a different speries, the Peuce acerosa Unger, belonging to an earlier geological epoch. From the brown-coal beds of Oberhart, near Gloggnitz, not far from Vienna. Reported also from Rosenthal near Köflach in Styria, and Prävali in Carinthia.

Dinite and Ixolyte belong here.
(d) The Benzole Series, General Formula $\mathrm{C}_{\mathrm{n}} \mathrm{H}_{2 \mathrm{n}-6}$. Including the Benzole liquids and Köncrite from Uznach, and Redwitz.
(e) The Naphthalin Series. General Formula $\mathrm{C}_{\mathrm{n}} \mathrm{H}_{2 \mathrm{n}-12}$.

Naphthalin.-Occurs in Rangoon tar. Idrialite, crystalline in the pure state. Color white. In nature found only impure, being mixed with cinnabar, clay, and some pyrite and gypsum in a brownish-black earthy material, called from its combustibility and the presence of metcury, inflammable cinnabar (Quecksilberbranderz). Idria, Spain. Aragotire, from New Almaden Mine, Cal., is related to idrialite.
2. The Oxygenated Hydrocarbons embrace different groups having ratios of $\mathrm{C}: \mathrm{H}$ varying from $1: 2$ to $5: 5 \frac{1}{2}$, or less. Some of the more important are:

Geocerite. Wax-like. Color white. Melting point near $80^{\circ} \mathrm{C}$. ; after fusion solidifies as a yellowish wax, hard but not very brittle. Soluble in alcohol of 80 p. c. $\mathrm{C}_{28} \mathrm{H}_{56} \mathrm{O}_{2}=$ Carbon $79 \cdot 24$, hydrogen $13 \cdot 21$, oxygen $7 \cdot 55=100$. From the same dark-brown brown coal of Gesterwitz that afforded the geomyricite, and from the same solution.

Geomyricite.-Wax-like. Obtained in a pulverulent form from a solution, the grains consisting of acicular crystals. Color white. Melting point $80^{\circ}-83^{\circ} \mathrm{C}$. After fusion has the aspect of a yellowish brittle wax. Soluble easily in hot absolute alcohol and ether, but slightly in alcohol of 80 p . c. $\mathrm{C}_{34} \mathrm{H}_{68} \mathrm{O}_{2}=$ Carbon 80.59 , hydrogen $13 \cdot 42$, oxygen $5 \cdot 99=100$. Burns with a bright flame. Occurs at the Gesterwitz brown coal deposit. in a dark brown layer.

## SUCCINITE. Amber. Succin, Ambre, Fr. Bernstein, Germ.

In irregular masses, without cleavage. $\mathrm{H} .=2-2 \cdot 5$. $\mathrm{G} .=1 \cdot 065-1 \cdot 081$. Lastre resinous. Color yellow, sometimes reddish, brownish, and whitish, often clouded. Streak white. Transparent-translucent. Tasteless. Eleetric on friction. Fuses at $287^{\circ} \mathrm{C}$., but without becoming a flowing liquid.

Comp.-Ratio for $\mathrm{C}: \mathrm{H}: \mathrm{O}=40: 64: 4=$ Carbon 78.94, hydrogen $10 \cdot 53$, oxygen $10 \cdot 53=$ 100. But amber is not a simple resin. According to Berzelius, it consists mainly ( 85 to 90 p. c.) of a resin which resists all solvents (properly the species succinite), along with two other resins soluble in alcohol and ether, an oil, and $2 \frac{1}{2}$ to 6 p . c. of succinic acid. Amber is hardly acted on by alcohol. Burns readily with a yellow flame, emitting an agreeable odor, and leaves a black, shining, carbonaceous residue.

Obs.-Occurs abundantly on the Prussian coast of the Baltic; occurring from Dantzig to Memel; also on the coast of Denmark and Sweden; in Galicia, near Lemberg, and at Miszau ; in Poland; in Moravia, at Boskowitz, etc. ; in the Urals, Russia ; near Christiania, Norway; in Switzerland, near Bâle; in France, near Paris, in clay. In England, near London, and on the coast of Norfolk, Essex, and Suffolk. In various parts of Asia. Also near Catania, on the Sicilian coast. It has been found in various parts of the Green sand formation of the United States, either loosely imbedded in the soil, or engaged in marl or lignite, as at Gay Head or Martha's Vineyard, near Trenton, and also at Camden in New Jersey, and at Cape Sable, near Magothy river in Maryland. In the royal museum at Berlin there is a mass weighing 18 lbs. Another in the kingdom of Ava, India, is nearly as large as a chuld's head, and weighs $2 \frac{1}{2} \mathrm{lbs}$.
It is now fully ascertained that amber is a vegetable resin altered by fossilization. This is inferred both from its native situation with coal, or fossil wood, and from the occurrence of insects incased in it. Of these insects, some appear evidently to have struggled after being entangled in the then viscous fluid; and occasionally a leg or a wing is found some distance from the body, which had been detached in the effort to escape.

Amber was early known to the ancients, and called $\eta^{\prime \prime} \kappa \kappa \tau \rho o v$, electrum, whence, on account of its electrical susceptibilities, we have derived the word electricity. It was named by some lyncurium, though this name was applied by Theophrastus also to a stone, probably to zircon or tourmaline, both minerals of remarkable electrical properties.

Other related resins are: Copalite (retinite pt.) from Highgate Hill, near London; Krantzite, Nienburg; Walchowite, Walchow, Moravia; Ambrite, N. Zealand; Bathe villite, occurring in the torbanite, or Boghead coal of Bathville, Scotland ; torbanite is related to it. Siegburgite, schraufite, Ambrosine, Duxite.

Xyloretinite (hartine).- $\mathrm{C}: \mathrm{H}: \mathrm{O}=40: 64: 4$. Bombiccite, $\mathrm{C}: \mathrm{H}: \mathrm{O}=13: 7: 1$, in lignite in the valley of the Arno, Tuscany. Leucopetrite. C $: \mathrm{H}: \mathrm{O}=50: 84: 3$. Gesterwitz, near Weissenfels. Euosmite. C : H: $0=34: 29: 2$, from the brown coal at Baiershof in the Fichtelgebirge. Rosthornite. C $: \mathrm{H}: \mathrm{O}=24: 40: 1$. In coal at Sonnberg, Carinthia. The above species are soluble in ether.

Scleretinite.-C $: \mathrm{H}: \mathrm{O}=40: 64: 4$. Insoluble in ether. Wigan, England.
Prroretinite, Jaulingite, Reubsinite, Guyaquillite, Wheelerite (New Mexico), etc. Ratio of $\mathrm{C}: \mathrm{H}=5: 7$ to $5: 6 \frac{1}{2}$.

Middletonite, Stanekite, Anthracoxenite. Ratio of $\mathrm{C}: \mathrm{H}=5: 5 \frac{1}{2}$ or less. Insoluable in ether or alcohol.

Tasmanite and Dysodile are remarkable in containing sulphur, replacing part of the oxygen.

The Acid Oxygenated Hydrocarbons include Butyrellite (Boghutter), Succinellite, Dopplerite, etc., etc.

## APPENDIX TO HYDROCARBONS.

## ASPHALTUM. Bitumen. Asphalt, Mineral Pitch. Bergpech, E dpech, Germ.

Asphaltum, or mineral pitch, is a mixture of different hydrocarbons, part of which are oxygenated. Its ordinary characters are as follows:

Amorphous. G. $=1-1 \cdot 8$; sometimes higher from impurities. Lustre like that of black pitch. Color brownisin-black and black. Odor bituminous. Melts ordinarily at $90^{\circ}$ to $100^{\circ} \mathrm{C}$., and burns with a bright flame. Soluble mostly or wholly in oil of turpentine, and partly or wholly in ether; commonly partly in alcohol.

The more solid kinds graduate into the pittasphalts or mineral tar, and through these there is a gradation to petroleum. The fluid kinds change into the solid by the loss of a vaporizable portion on exposure, and also by a process of oxidation, which consists first in a loss of hydrogen, and finally in the oxygenation of a portion of the mass.

Obs.-Asphaltum belongs to rocks of no particular age. The most abundant deposits are superficial. But these are generally, if not always, connected with rock deposits containing some kind of bituminous material or vegetable remains.

Some of the noted localities of asphaltum are the region of the Dead Sea, or Lake Asphaltites, on Trinidad; at various places in S. America, as at Caxitambo, Peru; at Berengela, Peru, not far from Arica (S.); in California, near the coast of st. Barbara. Also in smaller quantities, sometimes disseminated through shale, and sandstone rocks, and occasionally limestones, or collected in cavities or seams in these rocks; near Matlock, Derbyshire; Poldice mine in Cornwall; Val de Travers, Neuchatel ; impregnating dolomite on the island of Brazza in Dalmatia; in the Caucasus; in gneiss and mica schist in Sweden.

The following substances are closely related to asphaltum, and, like it, are mixtures of undetermined carbohydrogens.
Grailamite, Wurtz. - Resembles the preceding in its pitch-black, lustrous appearance; H. $=2 ; G .=1 \cdot 14 \tilde{j}$. Soluble mostly in oil of turpentine; partly in ether, naphtha, or benzole; not at all in alcohol; wholly in chloroform and carbon disulphide. No action with alkalies or hot nitric or hydrochloric acid. Melts only imperfectly, and with a decomposition of the surface ; but in this state the interior may be drawn into lnng threads. Occurs in W. Virginia, about 20 m . in an air line S . of Parkersburg, filling a fissure (shrinkage fissure) irı a sandstone of the Carboniferous formation; and supposed to be, like the albertite, an insrissated and oxygenated petroleum.
albertite, Robb.-Differs from ordinary asphaltum in being only partially soluble in oil of turpentine, and in its very imperfect fusion when heated. It has H. $=1-2 ; \mathrm{G} .=1.097$; lustre brilliant, pitch-like ; color jet-black. Softens a little in boiling water; in the flame of a candle shows incipient fusion. According to imperfect determinations, only a trace soluble in alcohol ; 4 p . c. in ether; 30 in oil of turpentine. Occurs filling an irregular fissure in rocks of the Subcarboniferous age (or Lower Carboniferous) in Nova Scotia, and is regarded as an inspissated and oxygenated petroleum. This and the above are very valuable in gas. making.

Piauzite.-An asphalt-like substance, remarkable for its high melting point, $315^{\circ} \mathrm{C}$. It occurs slaty massive; color brownish- or greenish-black ; thin splinters colophonite-brown by transmitted light; streak light brown, amber-brown ; H. $=1.5$; G. $=1 \cdot 220 ; 1 \cdot 186$, Kenngott. It comes from a bed of brown coal at Piauze, near Neustadt in Carniola ; on Mt. Chum, neax Tüffer in Styria.

Wollongongite, Silliman.-Occurs in cubic blocks without lamination. Fracture broad conchoidal. Color greenish- to brownish-black. Lustre resinous. In the tuke dces not melt, but decrepitates and gives off oil and gas; yieds by dry distillation 82.5 p . c. volatile matter Insoluble in ether or benzole. New South Wales.

## MINERAL COAL

The distinguishing characters of Mineral Coal are as follows: Compact massive, without crystalline structure or cleavage; sometimes breaking with a degree of regularity, but from a jointed rather than a cleavage structure. Sometimes laminated ; often faintly and delicately banded, successive layers differing slightly in lustre.
$H .=0.5-2 \cdot 5$. $\quad \in .=1-1 \cdot 80$. Lustre dull to brilliant, and either earthy, resinous, or submetallic. Color black, grayish-black, brownish-black, and oceasionally iridescent ; also sometimes dark brown. Opaque. Fracture conchoidal-uneren. Brittle; rarely somewhat sectile. Without taste, except from impurities present. Insoluble or nearly so in alcohol, ether, naphtha, and benzole. Infusible to subfusible; but often becoming a soft, pliant, or paste-like mass when heated. On distillation most kinds afford more or less of oily and tarry substances, which are mixtures of hydrocarhons and paraffin.

Mineral coal is made up of different kinds of hydrocarbons, with perhaps in some cases free carbou.

Var.-The variations depend partly (1) on the amount of the volatile ingredients afforded on destructive destillation; or (2) on the nature of these volatile compounds, for ingredients of similar composition may differ widely in volatility, etc. ; (3) on structure, lustre, and other physical characters.

1. Anthracite. $\mathrm{H} .=2-2 \cdot 5$. G. $=1 \cdot 32-1 \cdot 7$, Pennsylvania; $1 \cdot 81$, Rhode Island ; $1 \cdot 26-1 \cdot 36$, South Wales. Lustre bright, often submetallic, iron black, and frequently iridescent. Fracture conchoidal. Volatile matter after drying 3 to 6 p. c. Burns with a feeble flame of a pale color. The anthracites of Pennsylvania contain ordinarily 85 to 93 per cent. of carbon ; those of South Wales, 88 to 95 ; of France, 80 to 83 ; of Saxony, 81 ; of southern Russia, sometimes 94 per cent. Anthracite graduates into bituminous coal, becoming less hard, and containing more volatile matter; and an intermediate variety is called free-burning anthracite.

Bituminous Coals (Steinkohle pt., Germ.). Under the head of Bituminous Coals, a number of kinds are included which differ strikingly in the action of heat, and which therefore are of unlike constitution. They have the common characteristic of burning in the fire with a yellow, smoky flame, and giving out on distillation hydrocarbon oils or tar, and hence the name bituminous. The ordinary bituminous coals contain from 5 to $15 \mathrm{p} . \mathrm{c}$. (rarely 16 or 17) of oxygen (ash excluded) ; while the so-called brow coal or lignite contains from 20 to $36 \mathrm{p} . \mathrm{c} .$, after the expulsion, at $100^{\circ} \mathrm{C}$., of 15 to $36 \mathrm{p} . \mathrm{c}$. of water. The amount of hydrogen in each is from 4 to 7 p. c. Both have usually a bright, pitchy, greasy lustre (whence often called Pechkolle in German), a firm compact texture, are rather fragile compared with anthracite, and have G. $=1 \cdot 14-1 \cdot 40$. The brown coals have often a brownish-black color, whence the name, and more oxygen, but in these respects and others they shade into ordinary bituminous coals. The ordinary bituminous coal of Pennsylvania has G. $=1 \cdot 26-1 \cdot 37$; of Newcastle, England, $1 \cdot 27$; of Scotland, $1 \cdot 27-1 \cdot 32$; of France, $1 \cdot 2-1 * 33$; of Belgium, $1 \cdot 27-1 \% 3$. The most prominent kinds are the following:
2. Caking Coal. A bituminous coal which softens and becomes pasty or semi-viscid in the fire. This softening takes place at the temperature of incipient decomposition, and is attended with the escape of bubbles of gas. On increasing the heat, the volatile products which result from the ultimate decomposition of the softened mass are driven off, and a coherent, grayish-black, cellular, or fritted mass (coke) is left. Amount of coke left (or part not volatile) varies from 50 to 85 p. c. Byerite is from Middle Park, Colorado.
3. Non-Caking Coal. Like the preceding in all external characters, and often in ultimate composition; but burning freely without softening or any appearance of incipient fusion.
4. Cannef, Coal (Parrot Coal). A variety of bituminous coal, and often caking; but differing from the preceding in texture, and to some extent in composition, as shown by its products on distillation. It is compact, with little or no lustre, and without any appearance of a banded structure; and it breaks with a conchoidal fracture and smooth surfaces; color dull black or grayish-black. On distillation it affords, after drying, 40 to 66 of volatile matter, and the material volatilized includes a large proportion of burning and lubricating oils,
much larger than the above kinds of bituminous coal ; whence it is extensively used for the manufacture of such oils. It graduates into oil-producing coaly shales, the more compact of which it much resembles.
5. Torbanite. A variety of cannel coal of a dark brown color, yellowish streak, without lustre, having a subconchoidal fracture; $\mathrm{H} .=2 \cdot 25 ; \mathrm{G} .=1 \cdot 17-1 \cdot{ }^{2}$. Yields over 60 p . c. of volatile matter, and is used for the production of burning and lubricating oils, paraffin, illuminating gas. From Torbane Hill, near Bathgate in Linlithgowshire, Scotland. Also called Boghend Cannel.
6. Brown Coal (Braunkohle Germ.. Pechkohle pt. Germ., Lignite'. The prominent characteristics of brown coal have already been mentioned. They are non-caking, but afford a large proportion of volatile matter They are sometimes pitch-black (whence Pechkohle pt. Germ.), but often rather dull and brownish-black. G. $=1 \cdot 15-1 \%$; sometimes higher from impurities. It is occasionally somewhat lamellar in structure. Brown coal is often called lignite. But this term is sometimes restricted to masses of coal which still retain the form of the original wood. Jet is a black variety of brown coal, compact in texture, and taking a good polish, whence its use in jewelry.
7. Earthy Brown Coal (Erdige Braunkohle) is a brown friable material, sometimes forming layers in heds of brown coal. But it is in general not a true coal, a considerable part of it being soluble in ether and benzole, and often even in alcohol ; besides affording largely of oils and paraffin on distillation.

Comp.-Most mineral coal consists mainly, as the best chemists now hold, of oxygenated hydrocarbons. Besides oxygenated hydrocarbons, there may also be present simple hydrucarbons (that is, containing no oxygen).

Sulphur is present in nearly all coals. It is supposed to be usually combined with iron, and when the coal affords a red ash on burning, there is reason for believing this true. But Percy mentions a coal from New Zealand (anal. 18) which gave a peculiarly white ash, although containing 2 to 3 p . c. of sulphur, a fact showing that it is present not as a sulphide of iron, but as a constituent of an organic compound. The discovery by Church of a resin containing sulphur (see Tasmanite, p. 415), gives reason for inferring that it may exist in this coal in that state, although its presence as a constituent of other organic compounds is quite possible.

The chemical relations of the different kinds of coals will be understood from the following analyses:

1. Anthracite, S. Wales
2. Caking Coal, Northumberland
3. Non-Caking Coal, Zwickau
4. Cannel Coal, Wigan
5. Torbanite, Torbane Hill
6. Brown Coal, Meissen, Sax.

Carbon. Hydrogen. Oxygen. Nitrogen. Sulphur. Ash.
08.90

333
$\begin{array}{lllll}6.00 & 10.07 & 2.37 & 1.51 & 1.36\end{array}$ $\begin{array}{lllll}4.01 & 1098 & 0.49 & 2.99 & 1.57\end{array}$ $\begin{array}{lllll}5.53 & 8 \cdot 10 & 2 \cdot 12 & 1.50 & 2 \cdot 70\end{array}$ $\begin{array}{lllll}8.90 & 5.66 & 0.55 & 0.50 & 20.32\end{array}$ $\begin{array}{lllll}5 \cdot 36 & 21.63 & - & 6.61 & 7.50\end{array}$

Coal occurs in beds, interstratified with shales, sandstones, and conglomerates, and sometimes limestones, forming distinct layers, which vary from a fraction of an inch to 30 feet or more in thickness. In the United States, the anthracites occur east of the Alleghany range, in rocks that have undergone great contortions and fracturings, while the bituminous are found farther west, in rocks that have been less disturbed; and this fact and other observations have led some geologists to the view that the anthracites have lost their bitumen by the action of heat. The origin of coal is mainly vegetable, though animal life has contributed somewhat to the result. The beds were once beds of vegetation; analogous, in most respects, in mode of formation to the peat beds of modern times, yet in mode of burial often of a very different charac'er. This vegetable origin is proved not only by the occurrence of the leaves, stems, and logs of plants in the coal, but also by the presence throughout its texture, in many cases, of the forms of the original fibres; also by the direct observation that peat is a transition state between unaltered vegetable débris and brown coal, being sometimes found passing completely into true brown coal. Peat differs from true coal in want of homogeneity, it visibly containing vegetable fibres only partially altered; and wherever changed to a fine-textured homogeneous material, even though hardly consolidated, it may be true brown coal.

Extensive beds of mineral coal occur in Great Britain, covering 11,859 square miles; in France about $1,719 \mathrm{sq} . \mathrm{m}$. ; in Spain about $3,408 \mathrm{sq}$. m. ; in Belgium 518 sq . m. ; in Netherlands, Prussia, Bavaria, Austria, northern Italy, Silesia, Spain, Russia on the south near the Azof, and also in the Altai. It is found in Asia, abundantly in China, etc., etc.

In the United States there are four separate coal areas. One of these areas, the Appala chian coal field, commences on the north, in Pennsylvania and southeastern Ohio, and sweep
ing south over western Virginia and eastern Kentucky and Tennessee to the west of the Appalachians, or partly involved in their ridges, it continues to Alabama, near Tuscaloosa, where a bed of coal has been opened. It has been estimated to cover $60,000 \mathrm{sq} \cdot \mathrm{m}$. A second coal area (the Illinois) lies adjoining the Mississippi, and covers the larger part of Illinois, though much broken into patches, and a small northwest part of Kentucky. A third covers the central portion of Michigan, not far from $5,000 \mathrm{sq}$. m. in area. Besides these, there is a smaller coal region (a fourth) in Rbode Island. The total area of workable coal ineasures in the $\mathrm{I}^{\top}$ nited States is about $125,000 \mathrm{sq}$. m. Out of the borders of the United States, on the northeast, commences a fifth coal area, that of Nova Scotia and New Brunswick, which covers, in connection with that of Newfoundland, $18,000 \mathrm{sq}$. m.

The mines of western Pennsylvania. those of the States west, and those of Cumberland or Frostburg, Maryland, Richmond or Chesterfield, Va., and other mines south, are bituminous. Those of eastern Pennsylvania constituting several detached areas-one, the Schuylkill coal field-another, the Wzoming coal field-those of Rhode Island and Massachuset's, and some patches in Virginia, are anthracites. Cannel coal is found near Greensburg, Beaver Co., Pa., in Kenawha Co , Va., at Peytona, etc. ; also in Kentucky, Ohio, Illinois, Missouri, and Indiana; but part of the so-called cannel is a coaly shale.
Brown coal comes from coal beds more recent than those of the Carboniferous age. But much of this more recent coal is not distinguishable from other bituminous coals. The coal of Richmond, Virginia, is supposed to be of the Liassic or Triassic era; the coal of Brora, in Sutherland, and of Gristhorpe, Yorkshire, is Oolitic in age. Cretaceous coal occurs on Vancouver Island, and Cretaceous and Tertiary coal in many places over the Rocky Mountains, where a "Lignitic formation" is very widely distributed.

## PART III.-DESCRIPTIVE MINERALOGY.

## SUPPLEMENTARY CHAPTER.*

Abriachanite, Heddle.-A soft blue clay-like substance, filling seams and cavities in granite. Probably near crocidolite (p. 298) in composition. From the Abriachan district near Loch Ness, Scotland.

Adamite p. 373.-Occurs in colorless to deep green crystals, and in mammillary groups, at the ancient mines, recently reopened, at Laurium, Greece.

Aglaite.-Same as cymatolite ; that is, an alteration product of spodumene, consisting of an intimate misture of albite and muscovite. From Goshen, Mass.

Alaskaite, König.-Massive. G. $=6.878$. Lustre metallic. Color whitish lead-gray. Composition probably $\left(\mathrm{Ag}_{2}, \mathrm{Cu}_{2}, \mathrm{~Pb}\right) \mathrm{S}+\mathrm{Bi}_{2} \mathrm{~S}_{3}$. Analysis after deducting impurities, S $17 \cdot 63$, $\mathrm{Bi} 56 \cdot 97, \mathrm{Sb} 0 \cdot 62, \mathrm{~Pb} 11 \cdot 79, \mathrm{Ag} 8 \cdot 74, \mathrm{Cu} 3 \cdot 46, \mathrm{Zn} 0 \cdot 79=100$. From the Alaska mine, Poughkeepsie Gulch, Colorado. Silberwismuthglanz of Rammelsberg, from Morococha, Peru, is pure $\mathrm{Ag}_{2} \mathrm{~S}+\mathrm{Bi}_{2} \mathrm{~S}_{3}$.

Albite, p. 323.-Has been made artificially, identical in form and composition with natural crystals, by Hautefeuille.

Amblygonite, p. 369.-Penfield has analyzed specimens from Penig, Montebras, Hebron and Auburn, Me., Branchville, Ct. (including "hebronite" and "montebrasite"). He shows that, while the varieties vary from $\mathrm{F} 11 \cdot 26, \mathrm{H}_{2} \mathrm{O} 1 \cdot \% 5$ in one sample to $\mathrm{F} 1 \cdot 75, \mathrm{H}_{2} \mathrm{O} 6.61$, in another, they ail conform to the general formula: $\mathrm{Al}_{2} \mathrm{P}_{2} \mathrm{O}_{8}+2 \mathrm{R}(\mathrm{F}, \mathrm{OH})$, differing only in the extent to which the hydroxyl replaces the fluorine.

Amphibole, p. 296.-A variety containing only 0.9 p.c. M.gO, has been called bergamaskite by Lucchetti. Occurs in a hornblende porphyry. Monte Altino, Bergamo, Italy.

Phäactinite (Bertels) is a chloritic alteration product from a rock called isenite. Nassau, Germany.

Analcite, p. 343.-On the crystalline system, see p. 189.
Picranalcite, of Bechi. is identical with ordinary analcite, containing only a trace of magnesia, according to Bamberger.

Animikite, Wurtz.-An impure massive mineral supposed to be a silver antimonide (Sb $11 \cdot 18, \mathrm{Ag} 77 \cdot 58$ ). Silver Islet, Lake Superior.

Ånerödite, Brögger.-A rare columbate, almost identical with samarskite in composition, but in form very near columbite. From a pegmatite vein at Ånneröd, near Moss, Norway.

Apatite, p. 364.-Large deposits of apatite, affording sometimes gigantic crystals, and sometimes mined for commercial purposes, occur in Ottawa County, Quebec, Canada; also large crystals, with zircon, titanite and amphibole in Renfrew County, Ontario, and elsewhere ; there are similar deposits at Kjörrestad, Bamle, Norway. A variety from San Roque, Argentine Republic, containing $6^{\circ} 7$ p.c. MnO, has been called manganapatite by Siewert. Penfield found 10.6 p.c. MnO in a bluish-green specimen from Branchville, Ct.

Pseudo-hexagonal, Mallard, see p. 187.

[^52]Apophyllite, p. 340.-Pseudo-tetragonal (monoclinic), according to Mallard and Rumpf, but the correctness of their conclusions is doubtful ; see p. 185 et seq.

Aragonite, p. 405.-A variety from the Austin mine, Wythe Co., Va., afforded 7.29 p.c. $\mathrm{PbCO}_{3}$.

Arctolite, Blomstrand.-A doubtful silicate, composition near prehnite, prismatic angle near hornblende. Hvitholm, near Spitzbergen.

Arequipite, Raimondi.-A honey-yellow compact substance, supposed to be a silico-antimonate of lead, but probably a mixture. Victoria mine, Province of Arequipa, Peru.

Arfvedsontte, p. 298.-Occurs with zircon and astrophyllite in El Paso Co., Colorado.
Arrhente, Nordenskiöld.-A silico-tantalate of yttrium, erbium, etc., resembling feldspar in appearance. Probably an uncertain decomposition product. Ytterby, Sweden.

Arsenargentite, Hannay.-An uncertain silver arsenide of doubtful source.
Asmanite, p. 288.-According to Weisbach and v. Lasaulx, identical with tridymite ; observed in the meteoric iron of Rittersgrün, Saxony.

Astrophyllite, p. 313.-Referred to the triclinic system by Brögger ; properly a member of the pyroxene group, not one of the true micas.

Occurs with arfvedsonite and zircon in El Paso Co., Colorado.
Ateline (or atelite), Scacchi.-An alteration product of tenorite at Vesuvius ; near atacamite in composition.

Atopite, Nordenskiöld.-In isometric octahedrons. H. $=5 \cdot 5-6, \mathrm{G} .=5 \cdot 03$. Color yellow to brown. Composition essentially $\mathrm{Ca}_{2} \mathrm{Sb}_{2} \mathrm{O}_{7}$ (near romeite). Imbedded in hedyphane at Långban, Sweden.

Autunite, p. 379.-Monoclinic (or triclinic), according to Brezina.
Balvraidite; Heddle.-A doubtful substance having a saccharoidal structure, and pale purplish-brown color. G. $=2 \cdot 9$. An analysis gave, $\mathrm{SiO}_{2} 46.04, \mathrm{Al}_{2} \mathrm{O}_{3} 20 \cdot 11, \mathrm{Fe}_{2} \mathrm{O}_{3} 2 \cdot 52$, $\mathrm{MnO} 0 \cdot 79, \mathrm{MgO} 8 \cdot 30, \mathrm{CaO} 13 \cdot 4 \%, \mathrm{Na}_{2} \mathrm{O} 2 \cdot 72, \mathrm{~K}_{2} \mathrm{O} 1 \cdot 36, \mathrm{H}_{2} \mathrm{O} 4 \cdot 71=100 \cdot 0 \%$. In limestone at Balvraid, Inverness-shire, Scotland.

Barcenite, Mallet.-An uncertain alteration product of livingstonite, massive, earthy, color dark gray. G. $=53343$. Huitzuco, Guerrero, Mexico.

Barylite, Blomstrand. - In groups of prismatic crystals. Two distinct cleavages ( $84^{\circ}$ ). H. $=7$. G. $=4.03$. White. BB. infusible. A silicate of aluminum and barium (46 p.c. BaO ). In limestone at Långban, Sweden.

Beegerite, König.-In elongated isometric crystals. Cleavage cubic. G. $=7 \cdot 273$. Color gray. Lustre metallic. Composition, $6 \mathrm{PbS}+\mathrm{Bi}_{2} \mathrm{~S}_{3}=\mathrm{S} 14 \cdot 78$, $\mathrm{Bi} 21 \cdot 36, \mathrm{~Pb} 63 \cdot 84$ $=100$. From the Baltic Lode, Park Co., Colorado.

Beryl, p. 299.-Pseudo-hexagonal, according to Mallard, see p. 186.
A variety in short prismatic to tabular crystals has been called rosterite by Grattarola. Locality, Elba.

Found (W. E. Hidden) in fine crystals of large size (to 10 inches in length), and emerald color, in Alexander Co., N. C., also in highly modified crystals of pale. green color.

[^53]Bhreckite (or Vreckite), Heddle.-A doubtful soft apple-green substance, coating quartz crystals. A hydrous silicate of alumina, iron, magnesia and lime. From the hill Ben Bhreck, Sutherland, Scotland.

Bismutospherite, Weisbach.-In spherical forms, with concentric, fine fibrous radiated structure. Regarded as an anhydrous bismuth carbonate. From Neustädtel, Schneeberg, Saxony.

Blomstrandite, Lindström.-A columbo-titanate of uranium, allied to samarskite. From Nohl, Sweden.

Bolivite, Domeyko.-An alteration product of bismuthinite, probably a mechanical mixture of $\mathrm{Bi}_{2} \mathrm{O}_{3}$ and $\mathrm{Bi}_{2} \mathrm{~S}_{3}$. Mines of T'azna, Province of Choroloque, Bolivia.

Boracite, p. 381.-On the crystalline system, see p. 183.
Bowlingite, Hannay.-A soft, soapy, green substance, containing silica, alumina, iron, magnesia, lime, water ; doubtless heterogeneous. Bowling on the Clyde, Scotland.

Bravaisite, Mallard.-In fine crystalline fibres, of a grayish color, forming layers in the coal schists at Noyant, Allier Dep't, France. G. $=2 \cdot 6$. Analysis, $\mathrm{SiO}_{2} 51^{\circ} 4, \mathrm{Al}_{2} \mathrm{O}_{3} 18 \cdot 9$, $\mathrm{Fe}_{2} \mathrm{O}_{3} 4 \cdot 0, \mathrm{CaO} 2 \cdot \mathrm{U}, \mathrm{MgO} 3 \cdot 3, \mathrm{~K}_{2} \mathrm{O} 6 \cdot 5, \mathrm{H}_{2} \mathrm{O} 13 \cdot 3=99 \cdot 4$.

Brookite, p. 277.-In Mallard's view, brookite, rutile and octahedrite are all monoclinic, having the same primitive form, but differing in the way in which the individuals are grouped, see p. 186.

Brucite, p. 281.-Manganbrucite (Igelström) is a manganesian variety of brucite ( 14.16 MnO ) from the manganese mines of the Jakobsberg, Wermland, Sweden. In fine granular form with hausmannite in calcite.

Eisenbrucite, Sandberger.-A doubtful substance resulting from the alteration of bru cite. Sieberlehn near Freiberg.

Cabrerite.-Occurs in crystals (isomorphous with erythrite) at the zinc mines of Laurium, Greece An analysis by Damour corresponds to $\mathrm{Ni}_{3} \mathrm{As}_{2} \mathrm{O}_{8}+8$ aq.

Calamine, p. 329.-According to Groth, the formula should be written $\mathrm{H}_{2} \mathrm{Zn}_{2} \mathrm{SiO}_{5}$.
Calaverite, p. 249.-Occurs at the Keystone and Mountain Lion mines, Colorado. Composition (Genth) : ( $\mathrm{Au}, \mathrm{Ag}_{,} \mathrm{Te}_{2}$, with $\mathrm{Au}: \mathrm{Ag}=7: 1 . \mathrm{H} .=2 \cdot 5 . \quad \mathrm{G} .=9 \cdot 043$.

Cancrinite, p 317.-An original species (Rauff, Koch), and not an alteration product of nephelite, the carbon dioxide being essential and not due to calcite.

Caryinite, Lundström.-Massive, monoclinic ; two cleavages ( $130^{\circ}$ ). H. $=3-3.5$. G. $=4 \cdot 25$. Color, brown. Composition, $\mathrm{R}_{3} \mathrm{As}_{2} \mathrm{O}_{2}$, with $\mathrm{R}=\mathrm{Pb}, \mathrm{Mn}, \mathrm{Ca}, \mathrm{Mg}$. Occurs with calcite and hausmannite at Längban, Sweden.

Chabazite, p. 344.-Triclinic, according to Becke, the crystals being complex twins of several individuals.

Chalcomentte, Des Cloizeaux and Damour. --Monoclinic. $I \wedge I=108^{\circ} 20^{\prime} . \quad 0 \wedge i-i=$ $89^{\circ} 9^{\prime}$. G. $=3 \cdot 76$. Color, bright blue. Composition, $\mathrm{CuSeO}_{3}+2 \mathrm{aq}$, or a copper selenite. From the Cerro de Cacheuta, Mendoza, Argentine Republic.

Chalcopyrite, p. 244.-Found well crystallized, often coated with crystals of tetrahedrite in parallel position, near Central City, Gilpin Co , Colorado.

Childrenite, p. 377.-Formula, as shown by Penfield, $\mathrm{R}_{2} \mathrm{Al}_{2} \mathrm{P}_{2} \mathrm{O}_{10}+4 \mathrm{H}_{2} \mathrm{O}$, or $\mathrm{Al}_{2} \mathrm{P}_{2} \mathrm{O}_{8}+$ $2 \mathrm{RH}_{2} \mathrm{O}+2 \mathrm{aq}$, with $\mathrm{R}=\mathrm{Fe}$ principally, also Mn . This requires: $\mathrm{P}_{2} \mathrm{O}_{5} 30 \cdot 80, \mathrm{AlO}_{3} 22 \cdot 31$ $\mathrm{FeO} 26 \cdot 37, \mathrm{MnO} 4 \cdot 87, \mathrm{H}_{2} \mathrm{O} 15 \cdot 65$.

A mineral closely related to childrenite has been called eosphorite by Brush and E S.
Dana. Orthorhombic. In prismatic crystals (see fig.), near childrenite. $I \wedge I=104^{\circ} 19^{\prime} ; p \wedge p(1 \wedge 1)=183^{\circ} 3 \exists^{\prime}$ (front), $=118^{\circ}$ $58^{\prime}$ (side). Here $I$, and $a(i-\bar{\imath})=2-i$ and 0 of childrenite. Also massive, cleavable to compact. Cleavage parallel $a(i-\bar{i})$ nearly perfect. $\mathrm{H} .=5 . \quad \mathrm{G} .=311-3 \cdot 145$. Lustre vitreous to sub-resinous, also greasy. Color rose pink, yellowish, colorless, when compact various shades of white. Streak white. Transparent to translucent.
(ieneral formula like childrenite (see above), but with much manganese and little iron ( $10: 8$ ). Percentage composition: $\mathrm{P}_{2} \mathrm{O}_{5}$ $30 \cdot 93, \mathrm{Al}_{2} \mathrm{O}_{3} 2 \cdot \cdot 35, \mathrm{MnO} 23 \cdot 80, \mathrm{FeO} 7 \cdot 24, \mathrm{H}_{2} \mathrm{O} 15 \cdot 68=100$. B. B. in the forceps cracks opens, sprouts and whitens, colors the flame pale green and fuses at 4 to a black magnetic mass. Reacts for manganese and iron ; is soluble in acids. Occurs with other manganesian phosphates in a vein of pegmatite at Branchville, Conn.


Chloralluminite, Ścacchi.-Hydrous aluminum chloride from Vesuvius.
Chloromagnesite, Scacchi.-Hydrous magnesium chloride from Vesuvius. Bischofite (Ochsenius and Pfeiffer) from Leopoldshall, Prussia, has the composition $\mathrm{MgCl}_{2}+6$ aq. Crystalline, massive, foliated or fibrous. Color white. Forms thin layers in halite, with kieserite and carnallite. Readily assumes water on exposure.

Chlorothionite, Scacchi.-Regarded as a compound salt, $\mathrm{K}_{2} \mathrm{SO}_{4}+\mathrm{CuCl}_{2}$, forming thin mammillary crusts of a blue color. Vesuvius.

Chondrodite, Humite, Clinohumite, p. 327.-H. Sjögren has described humite, well crystallized, from the Ladu mine, Wermland, Sweden, and chondrodite from Kaveltorp.

Chromite, p. 274.-Not opaque, but in thin sections transmits a yellowish red color, Thoulet. Identified in meteoric irons by J. Lawrence Smith.

Chrysocolla, p. 338.-Pilarite, from Cinili, is an aluminous variety, 16.9 p.c. $\mathrm{Ai}_{2} \mathrm{O}_{3}$.
Chrysolite, p. 300.-Neochrysolite (Scacchi) is a manganesian variety from Vesuvius. A variety from Zermatt, containing 6 p.c. $\mathrm{TiO}_{2}$, has been called titanolivine.

Cleveite, Nordenskiöld.-A mineral closely related to uraninite, but besides uranium (and lead) contains yttrium, erbium, cerium, etc. In isometric crystals. H. $=55$. G. $=7.49$. Color iron black A decomposition product of a yellow color is called yttrogummite (analogous to ordinary gummite). Occurs in feldspar at Garta, near Arendal, Norway.

Clinocrocite, Sandberger, Singer.-An imperfectly described sulphate of iron, etc., occurring in saffron-yellow microscopic crystals, derived from the decomposition of pyrite at the Bauersberg, near Bischofsheim vor der Rhön. Clinophaeite, from the same source, occurs in blackish green microscopic crystals ; formula $5 \mathrm{R}_{2} \mathrm{SO}_{4}+\left[\mathrm{R}_{2}\right] \mathrm{H}_{6} \mathrm{O}_{6}+5$ aq, with $\left[\mathrm{R}_{2}\right]=\mathrm{Fe}_{2}, \mathrm{Al}_{2}$, and $\mathrm{R}_{2}=\mathrm{Fe}, \mathrm{K}_{2}, \mathrm{Na}_{2}$.

Clintonite, p. 358.-On the relations of the "clintonite group" of minerals, see T'schermak and Sipöcz, Z. Kryst., iii., 496.

Coloradoite, Genth.-Massive, granular. H. $=3$. G. $=8.627$. Lustre metallic. Color iron black. Composition $\mathrm{HgTe}=$ tellurium 39 , mercury $61=100$. Occurs with native tellurium, sylvanite, gold, at the Keystone, Mountain Lion, and Smuggler mines in Colorado.

Columbite, p. 360.-Occurs sparingly in small translucent crystals at Branchville, Conn.,
 Also the ordinary variety in groups of very large, though rough, crystals, weighing sometimes 50 pounds, at the same locality. Found with amazonstone at Pike's Peak, Colorado.
and in Yancey Co., N. C. Also with monazite, orthite, etc., in Amelia County, Virginia, allied in composition to the above manganesian variety from Branchville.

Coronguite, Raimondi.-An earthy, pulverulent substance of a gray to black color. Containing antimony pentoxide, lead, and silver oxides, water, but of doubtful homogeneity. District of Corongo and elsewhere in Peru.

Corundophilite, p. 358.-Amesite of Shepard, from Chester, Mass., is very near corundophilite.

Corundum, p. 267.-Monoclinic according to Tschermak (orthorhombic, Mallard) ; often optically biaxial. See p. 18.5 et seq.

Made artificially, with the colors of rubies and sapphires, by Frémy and Feil.
Cosalite, p. 252.-Bjelkite of H. Sjögren is identical with cosalite. From the Bjelke mine, Nordmark, Sweden.

Cossyrite, Foerstner.-Near amphibole in form, but triclinic, and with $I \wedge I^{\prime}=$ $114^{\circ} 5^{\prime}$. Cleavage prismatic. G. $=3 \cdot 75$. Color black. An analysis gave : $\mathrm{SiO}_{2} 43 \cdot 55$, $\mathrm{Al}_{2} \mathrm{O}_{3} 4 \cdot 96, \mathrm{Fe}_{2} \mathrm{O}_{3} 7 \cdot 97$, $\mathrm{FeO}, 32 \cdot 87$, $\mathrm{MnO} 1 \cdot 98$. $\mathrm{CuO} 0 \cdot 39, \mathrm{MgO} 0 \cdot 86$, $\mathrm{CaO} 2 \cdot 01, \mathrm{Na}_{2} \mathrm{O} 5 \cdot 29$, $\mathrm{K}_{2} \mathrm{O} 0 \cdot 33=100 \cdot 21$. In minute crystals weathered out of the ground mass of the liparite lavas of the Island Pantellaria (ancient name Cossyra).

Craigtonite, Heddle.-Doubtful mineral, contains $\mathrm{Al}_{2} \mathrm{O}_{3}, \mathrm{Fe}_{2} \mathrm{O}_{3}, \mathrm{MgO}$, etc. Dendrites in granite at Craigton, Aberdeenshire, Scotland.

Crocorte, p. 385.-Described by B. Silliman as occurring at the Phenix and other mines in Yavapai Co., Arizona.

Cryolite, p. 264.-Observations of Krenner make cryolite monoclinic instead of triclinic.
Cryolite and some related fluorides have been found (Cross and Hillebrand) in the Pike's Peak region, El Paso ('o., Colorado.

Cuprocalcite, p. 411.-Mechanical mixture of $\mathrm{CaCO}_{3}$ and $\mathrm{Cu}_{2} \mathrm{O}$, Damour.
Cuspidine, Scacchi.-In spear-shaped monoclinic crystals ; color pale rose red. A calcium silicate containing fluorine. Vesuvius.
ctyanite, p. 332.-Recently found in well terminated crystals, Bauer, vom Rath.
Cyprusite, Reinsch - A supposed anhydrous iron sulphate, occurring in the western part of the island of Cyprus. Soft. Color yellow. Analysis : $\mathrm{SO}_{3} 21 \cdot 5, \mathrm{Fe}_{2} \mathrm{O}_{3}\left(\mathrm{Al}_{2} \mathrm{O}_{3} \mathrm{tr}\right.$.) $51 \cdot 5$, insol. silica (shells of Radiolaria) 25, $\mathrm{H}_{2} \mathrm{O}$ (hygrosc.) $2=100$.

Danalite, p. 302.-Occurs at the iron mine of Bartlett, N. H. (Wadsworth).
Danburite, p. 311. Occurs (G. J. Brush and E. S. Dana) well crystallized and abundant at Russell, N. Y. Orthorhombic, homœomorphous with topaz and like it in habit. I $I$ $=122^{\circ} 52^{\prime}\left(\right.$ topaz $\left.=124^{\circ} 17^{\prime}\right), w \wedge w=54^{\circ} 58^{\prime}$ (topaz $\left.=55^{\circ} 20^{\prime}\right), d \wedge d=97^{\circ} 7^{\prime}\left(\right.$ topaz $\left.=96^{\circ} 6^{\prime}\right)$. Common forms as in figures, $w=4-\breve{\imath}, d=1-\bar{\imath}, l=i-2, n=i-4, r=2-2$. Color pale wine or honey yellow, colorless. Transparent. Composition $\mathrm{CaB}_{2} \mathrm{Si}_{2} \mathrm{O}_{8}$, as of Danbury mineral.


Also from the Skopi, Switzerland, in transparent crystals.

Davreuxite, de Koninck.-In aggregates of minute acicular crystals. Color white, with tinge of red. Calculated composition : $\mathrm{SiO}_{2} 46 \cdot 89, \mathrm{Al}_{2} \mathrm{O}_{3} 40 \cdot 19$, $\mathrm{MnO} 6 \cdot 93, \mathrm{MgO} 1 \cdot 30$, $\mathrm{H}_{2} \mathrm{O} 4.69=100$. Occurs in quartz veins in the Ardennes schists at Ottre, Belgium.

Dawsonite, p. 410.-Occurs (Chaper) in the province of Siena, Pian ('astagnaio, Tuscany. Analysis gave Friedel : ( $\frac{2}{2}$ ) $\mathrm{CO}_{2} 29 \cdot 09, \mathrm{Al}_{2} \mathrm{O}_{3} 35 \cdot 89, \mathrm{Na}_{2} \mathrm{O} 19 \cdot 13, \mathrm{H}_{2} \mathrm{O}$ 12.00, MgO 1•39, $\mathrm{CaO} 0 \cdot 42$.

Delessite, p. 356.-More or less related to the chloritic delessite are: Subdelessite from the Thüringer Wald ; Hullite, Carnmoney Hill, near Belfast, Ireland.

Descloizite, p. 367.-Occurs in the Sierra de Cordoba, Argentine Republic ; perhaps also in Arizona. Composition of South American mineral (Rammelsberg) $\mathrm{R}_{3} \mathrm{~V}_{2} \mathrm{O}_{8}+\mathrm{RH}_{2} \mathrm{O}_{2}$, with $\mathrm{R}=\mathrm{Pb}$ (56 p.c.), Zn (17 p.c.)

Brackebuschite from Cordoba, Argentine Republic, occurs in small striated crystals. Color black. Composition perhaps $\mathrm{R}_{3} \mathrm{~V}_{2} \mathrm{O}_{8}+\mathrm{H}_{2} \mathrm{O}$, with $\mathrm{R}=\mathrm{Pb}: \mathrm{Fe}: \mathrm{Mn}=4: 1: 1$.

Destinezite, Forir and Jorissen.-An iron phosphate from Argenteau, Belgium; occurs in yellowish white earthy masses.

Diamond, p. 228.-Has been made artificially, in the form of a fine sand, by J. B. Hannay.
Dickinsonite, G. J. Brush and E. S. Dana.-Monoclinic, pseudo-rhombohedral, $\beta=61^{\circ}$ 30 . $c \wedge a=118^{\circ} 30^{\prime}, c \wedge p=118^{\circ} 52^{\prime}, c \wedge s=97^{\circ} 58^{\prime} ; c=0, p=1, s=2, x=-3-i$. Commonly foliated to micaceous. Cleavage basal perfect. H. $=3 \cdot 5-4$. G. $=3 \cdot 338-3 \cdot 34$. . Lustre vitreous, on $c$ pearly. Color various shades of green. Composition $4 \mathrm{R}_{3} \mathrm{P}_{2} \mathrm{O}_{8}+3 \mathrm{aq}$. with $\mathrm{R}=\mathrm{Mn}, \mathrm{Fe},{ }^{\prime} \cdot \mathrm{a}, \mathrm{Na}_{2}$, requiring : $\mathrm{P}_{2} \mathrm{O}_{5} 40 \cdot 05, \mathrm{FeO} 12 \cdot 69, \mathrm{MnO} 25 \cdot 04, \mathrm{CaO} 11 \cdot 85$, $\mathrm{Na}_{2} \mathrm{O} 6.56, \mathrm{H}_{2} \mathrm{O} 3.81=10 \mathrm{~J}$. Occurs with eosphorite, triploidite, etc., in pegmatite at Branchville, Conn.

Dietrichite, v. Schröckinger.-A zinc-iron-manganese alum, related to mendozite, etc. A recent formation at Felsöbanya, Transylvania.

Dopplerite, p. 415. - A black gelatinous hydrocarbon from a stratum of muck below a peat bed at Scranton, Penn., is called by H. C. Lewis phytocollite; empirical formula $\mathrm{C}_{10} \mathrm{H}_{22} \mathrm{O}_{16}$.

Douglasite, Ochsenius, Precht.-From Douglasshall, formula, $2 \mathrm{KCl}, \mathrm{FeCl}_{2}, 2 \mathrm{H}_{2} \mathrm{O}$.
Dumortierite, Damour, Bertrand.-In minute prismatic crystals of a cobalt blue color, imbedded in gneiss. Analysis (Damour) : $\mathrm{SiO}_{2} 29 \cdot 85, \mathrm{Al}_{2} \mathrm{O}_{3} 66.02, \mathrm{Fe}_{2} \mathrm{O}_{3} 1 \cdot 01, \mathrm{MgO} 0.45$, ign. $2 \cdot 25=99^{\circ} 58$; near andalusite. From the gneiss at Chaponost, near Lyons, France.

Duporthite, Collins.-An asbestiform mineral filling fissures in serpentine. Color greenish to brownish gray. Contains silica, alumina, iron, magnesia, and water. Duporth, St. Austell, Cornwall.

Dürfeldtite, Raimondi.-Massive, indistinctly fibrous. Color light gray. Metallic. Composition 3RS $+\mathrm{Sb}_{2} \mathrm{~S}_{3}$ (if the results of an analysis after deducting 31 p.c. gangue can be trusted), with $\mathrm{R}=\mathrm{Pb}, \mathrm{Ag}_{2}, \mathrm{Mn}$, also $\mathrm{Fe}, \mathrm{Cu}_{2}$. From the Irismachay mine, Anquimarca, Peru.

Dysanalyte, Knop.-The perofskite of the Kaiserstuhl is, according to Knop, a new columbo-titanate of calcium and iron (with also (e, Na).

Eggonite, Schrauf.-In minute, grayish-brown crystals (triclinic) near barite in habit. Supposed to be a cadmium silicate. Occurs with calamine and smithsonite at Altenberg.

Ekdemite, Nordenskiöld.-Massive, coarsely granular, also incrusting. Cleavage basal. H. $=2 \cdot 5-3 . \quad$ G. $=7 \cdot 14$. Color bright yellow to green Composition $\mathrm{Pb}_{5} \mathrm{As}_{2} \mathrm{O}_{8}+2 \mathrm{PbCl}_{2}$ $=\mathrm{As}_{2} \mathrm{O}_{3} 10 \cdot 59, \mathrm{PbO} 59 \cdot 67, \mathrm{Cl} 7 \cdot 58, \mathrm{~Pb} 22 \cdot 16=100$. Found at Långban, Sweden.

Eleonorite, Nies.-Monoclinic ; often in druses and in radiated crusts. Cleavage orthodiagonal. H. $=3-4$. Lustre vitreous. Color red brown to dark hyacinth red. Sireak yellow. Composition (Streng) $2 \mathrm{Fe}_{2} \mathrm{P}_{2} \mathrm{O}_{8}+\mathrm{Fe}_{2} \mathrm{H}_{6} \mathrm{O}_{6}+5$ aq. From the Eleonore mine on the Dünsberg, near Giessen, and the Rothläufchen mine near Waldgirmes. Perhaps identicel with the iron phosphate beraunite from Benigna, Bohemia.

Ellonite, Heddle.-Impure silicate of magnesia, containing $\mathrm{SiO}_{2}$. In gneiss near Ellon, Aberdeenshire, Scotland.

Elroquite, Shepard.-A heterogeneous substance containing silica, alumina, iron oxide, water and (as an impurity) 32 p.c. $\mathrm{P}_{2} \mathrm{O}_{5}$. Island of Elroque, Caribbean Sea.

Enysite, Collins.-A bluish-green stalagmitic substance consisting of aluminum hydrate, basic copper sulphate, calcite, etc. St. Agnes, Cornwall.

Epistilbite, p. 347.-Monoclinie, Des Cloizeaux. Parastilbite and reissite are probably identical.

Epsomite, p. 394.-Reichardtite (Krause) is a massive variety from Stassfurt and Leopoldshall.

Erilite, Lewis.-Acicular, wool-like crystals of unknown nature occurring in a cavity in the quartz from Herkimer Co., N. Y.

Eriochalcite, Scacchi.-Copper chloride from Vesuvius.
Erythrozincite, Damour.-In thin crystalline plates. Color red. Perhaps (Des Cloizeaux) a manganesian variety of wurtzite.

Euclase, p. 323.-Found in good crystals in the Tyrol, from the Hohe Tauern, perhaps at Rauris.

Eucrasite, Paijkull.-A mineral from Brevig, Norway, near thorite.


Eucryptite, G. J. Brush and E. S. Dana.-Hexagonal. In regularly arranged crystals imbedded in albite (like graphic granite, see fig.) both of which have resulted from the alteration of spodumene. G. $=2 \cdot 66 \%$. Composition $\mathrm{Li}_{2} \mathrm{Al}_{2} \mathrm{Si}_{2} \mathrm{O}_{8}=\mathrm{SiO}_{2} 47 \cdot 51, \mathrm{Al}_{2} \mathrm{O}_{3} 40 \cdot 61$, $\mathrm{Li}_{2} \mathrm{O} 11 \cdot 88=100$. Branchville, Conn.

Eulytite, p. 302.-Pseudo rhombohedral according to Bertrand.

Eusynchite is (Rammelsberg) $4 \mathrm{~Pb}_{3} \mathrm{~V}_{2} \mathrm{O}_{8}+3 \mathrm{Zn}_{3} \mathrm{~V}_{2} \mathrm{O}_{8}$. Aräoxene is $2(\mathrm{~Pb}, \mathrm{Zn})_{3} \mathrm{~V}_{2} \mathrm{O}_{8}+(\mathrm{Pb}, \mathrm{Zn})_{3} \mathrm{As}_{2} \mathrm{O}_{8}$.

Tritochorite (Frenzel) is related, composition $\mathrm{R}_{3} \mathrm{~V}_{2} \mathrm{O}_{8}$, with $\mathrm{R}=\mathrm{Pb}$ ( 54 p.c.), Cu (7 p.c.), Zn (11 p.c.). Locality uncertain.

Filrfieldite. G. J. Brush and E. S. Dana.-Triclinic. Foliated or lamellar, crystalline; also in radiating masses, curved foliated or fibrous. Cleavage brachydiagonal perfect. Lustre pearly to subadamantine. Color white to pale straw yellow. Transparent. Composition $\mathrm{R}_{3} \mathrm{P}_{2} \mathrm{O}_{8}+9 \mathrm{aq}$, with $\mathrm{R}=\mathrm{Ca}:(\mathrm{Mn}+\mathrm{Fe})=2: 1$. This requires : $\mathrm{P}_{2} \mathrm{O}_{5} 39 \cdot 30, \mathrm{Fe} \mathrm{O}$ 6.64. MnO $13 \cdot 10, \mathrm{CaO} 30 \cdot 99, \mathrm{H}_{2} \mathrm{O} 9 \cdot 97=100$. Occurs with other manganesian phosphates at Branchville, Conn.

Leucomanganite (Sandberger) from Rabenstein, Bavaria, may be identical; not yet described.

Feldspar Group.-Schuster has shown that in the series of triclinic feldspars there is
in optical relations the same gradual transition from the one extreme (albite) to the other (anorthite) as exists in composition. Thus, he finds that the directions of light-extinction, as observed on the basal and clinodiagonal sections, the position of the axes of elasticity, the dispersion of the axes, and the axial angle all show this gradual change in the same direction. These results confirm the accepted view of Tschermak that the intermediate triclinic feldspars are to be regarded as isomorphous mixtures of albite and anorthite in varying proportions ; moreover, they explain the apparent difficulties raised by the observations of Des Cloizeaux (p. 319). The angles given on p. 320 are then true only in special cases. since in the varieties varying in composition these values will also vary. The values for angles (given by Schuster) made by the extinction-directions with $O$ and $i-\check{\imath}$ are as follows :

|  | With $O$ |  |  | With $i-\imath$ 亿 |  |
| :---: | :---: | :---: | :---: | :---: | :---: |
| Albite | $+4^{\circ}$ | to | $+3^{\circ}$ | $+18^{\circ}$ |  |
| Varieties between Albite \} and Oligoclase. | $+2^{\circ}$ | to | $+1^{\circ}$ | $+12^{2}$ |  |
| Oligoclase. . . . . . . . . . . . . . . | $+2^{\circ}$ | to | $+1^{\circ}$ | $+3^{\circ}$ | to $+2^{\circ}$ |
| Andesite | $-1^{\circ}$ | to | $-2^{\circ}$ | $-4^{\circ}$ | to $-6^{\circ}$ |
| Labradorite | $-4^{\circ}$ | to | $-5^{\circ}$ | $-17^{\circ}$ |  |
| Varieties between Labradorite and Anorthite. ... | $-16^{\circ}$ | to | $-18^{\circ}$ | $-29^{\circ}$ |  |
| Anorthite. . . . . . . . . . . . . . | $-38^{\circ}$ |  |  | $-40^{\circ}$ |  |

Fergusonite, p. 362.-New localities: Rockport, Mass. (J. L. Smith) ; Burke Co., N. C. (Hidden) ; Mitchell Co., N. C. (Shepard).

Ferrotellurite, Genth.-In delicate radiating crystalline tufts of a yellow color. Perhaps an iron tellurate. Keystone mine, Magnolia District, Colorado.

Fillowite, G. J. Brush and E. S. Dana.-Monoclinic ; pseudo-rhomboheāral. Generally in granular crystalline masses. $H .=4 \%$. G. $=3 \cdot 43$. Lustre subresinous to greasy. Color wax yellow, yellowish to reddish brown. Composition $3 \mathrm{R}_{3} \mathrm{P}_{2} \mathrm{O}_{8}+$ aq, with $\mathrm{R}=\mathrm{Mn}$, Fe , $\mathrm{Ca}, \mathrm{Na}_{2}$; requiring: $\mathrm{P}_{2} \mathrm{O}_{5} 40 \cdot 19, \mathrm{FeO} 6 \cdot 80$, $\mathrm{MnO} 40 \cdot 19, \mathrm{CaO} 5 \cdot 28, \mathrm{Na}_{2} \mathrm{O} 5 \cdot 84, \mathrm{H}_{2} \mathrm{O} 1 \cdot \% 0$ $=100$. Occurs with other manganesian phosphates in pegmatite at Branchville, Conn.

Fluorite, p. 263.-Pseudo-isometric, according to Mallard ; see p. 186.
Foresite, p. 347.-Probably identical with stilbite.
Franklandite, Reynolds.-Near ulexite. Massive. White. G. $=1.65$. Composition $\mathrm{Na}_{4} \mathrm{Ca}_{2} \mathrm{~B}_{12} \mathrm{O}_{22}, 15 \mathrm{H}_{2} \mathrm{O}$. Tarapaca, Peru.

Freyalite, Esmark, Damour.-A silicate of cerium, thorium, etc. G. $=4 \cdot 06-4 \cdot 1 \%$. Color brown. From Brevig, Norway.

Gadolinite, p. 309.-Contains the new earth ytterbium (Marignac), also scandium (Cleve)
Galenobismutite, H. Sjögren.-Massive, compact. H. $=3-4 . \quad$ G. $=6.88$. Lustre me, tallic. Color tin white. Streak grayish black. Composition $\mathrm{PbBi}_{2} \mathrm{~S}_{4}$ or $\mathrm{PbS}+\mathrm{Bi}_{2} \mathrm{~S}_{3}$, requiring, $\mathrm{S} 16 \cdot 95, \mathrm{Bi} 55 \cdot 62, \mathrm{~Pb} 2 \% \cdot 43=100$. Occurs with bismutite at the Kogrufva, Nordmark, Sweden.

Ganomalite, Nordenskiöld.-Nassive. $\mathrm{H}_{\mathrm{F}}=4 . \mathrm{G}_{\mathrm{F}}=4.98$. Lustre greasy. Colorless to white or whitish gray. Transparent. Composition ( $\mathrm{Pb}, \mathrm{Mn}$ ) $\mathrm{SiO}_{3}$; analysis (Lindström : $\mathrm{SiO}_{2} 34 \cdot 55, \mathrm{PbO} 34 \cdot \mathrm{~S} 9, \mathrm{MnO} 20 \cdot 01$, $\mathrm{CaO} 4 \cdot 59, \mathrm{MgO} 3 \cdot 68$, alk., ign. $1 \cdot 88=99 \cdot 58$. Occurs with tephroite, native lead, etc., at Lángban, Sweden.

Garnet, p. 302.-Pseudo-isometric, eccording to Mallard and Bertrand, see p. 186. Nearly colorless garnets nccur at Hull, Canada ; others containing 5 p.c. $\mathrm{Cr}_{2} \mathrm{O}_{3}$ at Wakefield, Quebec. Large perfect crystals in mica schist near Fort Wrangell, Alaska.

Garnierite, p. 351.-An allied hydrated silicate of magnesium and nickel has been found in Southern Oregon, at Piney Mountain, Cow Creek, Douglas County.

Ginilsite, Fischer.-A doubtful silicate from the Ginilsalp, Graubünden, Switzerland.
Gismondite, p. 341.-Triclinic, complex twins, according to Schrauf and v. Lasaulx.
Guanajuatite, Fernandez, 1873. - The same mineral as that afterward called frenzelite (p. 223). Composition (Mallet), $\mathrm{Bi}_{2} \mathrm{Se}_{3}$, with a little Se replaced by S. Silaonite is a mechanical mixture of this mineral and native bismuth.

Gunnisonite, Clarke and Perry (Am. Chem. Journ., iv., 140).-A massive substance, of a deep purple color, mixed with calcite. An analysis, after deducting $12.75 \mathrm{CaCO}_{3}$, yielded $\mathrm{CaF}_{2} 74 \cdot 89, \mathrm{CaO} 11 \cdot 44, \mathrm{SiO}_{2} 6 \cdot 87, \mathrm{Al}_{2} \mathrm{O}_{3} 5 \cdot 95, \mathrm{Na}_{2} \mathrm{O} 0 \cdot 85=100$. Probably an impure fluorite ; perhaps altered ; certainly not a homogeneous mineral.

Guejarite, Cumenge. - Orthorhombic ; in prismatic crystals, form near that of chalcostibite. H. $=3 \cdot 5$. G. $=5 \cdot 03$. Color steel gray. Composition $\mathrm{Cu}_{2} \mathrm{Sb}_{4} \mathrm{~S}_{7}$ or $\mathrm{Cu}_{2} \mathrm{~S}+2 \mathrm{Sb}_{2} \mathrm{~S}_{3}$. From the copper mines in the district of Guejar, Andalusia.

Gummite.-This decomposition product of uraninite occurs in considerable masses at the Flat Rock mine, Mitchell Co., N. C.

Gyrolite, p. 328.-Tobermorite of Heddle, is near gyrolite and okenite. Massive. Color pinkish white. G. $=2 \cdot 423$. Analysis : $\mathrm{SiO}_{2} 46 \cdot 62, \mathrm{Al}_{2} \mathrm{O}_{3} 3 \cdot 99, \mathrm{~F}_{2} \mathrm{O}_{3} 0 \cdot 66, \mathrm{FeO} 1 \cdot 08$, CaO $33 \cdot 98, \mathrm{~K}_{2} \mathrm{O} 0 \cdot 57, \mathrm{Na}_{2} \mathrm{O} 0 \cdot 89, \mathrm{H}_{2} \mathrm{O} 12 \cdot 11=99 \cdot 81$. Filling cavities in rocks near Tobermory,
Island of Mull.

Halloysite, p. 352. - Indianaite of Cox, is a white porcelain clay, useful in the arts, occurring in considerable beds in Lawrence Co., Indiana.

Hannayite, vom Rath.-In triclinic prismatic crystals. G. $=1.893$. Composition $\mathrm{H}_{4}\left(\mathrm{NH}_{4}\right) \mathrm{Mg}_{3} \mathrm{P}_{4} \mathrm{O}_{18}+8$ aq. Occurs in guano of the Skipton Caves, Victoria.

Hatchettrolite, J. L. Smith.-Isometric, habit octahedral. H. $=$ 5. G. $=4 \cdot 77-4 \cdot 90$. Lustre resinous. Color yellowish brown. Translucent. Fracture conchoidal. A columbo-tantalate of uranium and calcium, containing 5 p.c. water; closely related to pyrochlore. With samarskite in the mica mines of Mitchell Co., N. C.

Hayesine.-According to N. H. Darton, this borate occurs sparingly with datolite and calcite at Bergen Hill, N. J.

Hedyphane, p. 367.-A variety from Långban contains (Lindström) 8 p.c. BaO. Monoclinic (Des Cloizeaux), and perhaps isomorphous with caryinite, p. 432 ; this would separate it from mimetite.

Heldburgite, Lüdecke.-In minute tetragonal crystals, resembling guarinite. Color yellow. $\underset{\text { near Coburg. }}{\mathrm{H}}=6.5$. Composition unknown. In feldspar of the phonolyte of the Heldburg, near Coburg.

Helvite, p. 302.-Occurs at the mica mine near Amelia Court House, Amelia Co., Virginia. In crystals and crystalline masses, of a sulphur-yellow color, imbedded in orthoclase.

Henwoodite, Collins.-In botryoidal globular masses, crystalline. H. $=4-4.5$. G. $=2 \cdot 67$. Color turquoise blue. A hydrous phosphate of aluminum and copper ( 7 p.c. CuO ). West Phenix mine, Cornwall.

Herrengrundite, Brezina ( = Urvölgyite, Szabó).-In spherical groups of six-sided tabular crystals (monoclinic). Cleavage basal perfect. $H .=2 \cdot 5 . \mathrm{G} .=3 \cdot 132$. Lustre vitreous, pearly on cleavage face. Color emerald to bluish green. A hydrous basic sulphate of copper, allied to langite. From Herrengrund ( $=$ Urvölgy) in Hungary.

Hessite, p. 228.-Pseudo-isometric (triclinic) according to Becke, but the conclusion is not beyond question.

Heterolite (Hetairite), G. E. Moore. - In botryoidal coatings, with radiated structure. $\mathrm{H} .=5 . \quad \mathrm{G} .=4 \cdot 933$. Stated to be a zinc hausmannite. Occurs with chalcophanite at Sterling Hill, New Jersey.

Heubachite, Sandberger.-In thin soot-like incrustations, also dendritic. Color black. A hydrous oxide of cobalt and nickel. Heubachithal, near Wittichen, Baden.

Heulandite, p. 347.-Oryzite of Grattarola may be identical with heulandite. In minute white crystals, resembling rice grains (öpv弓 $\alpha$, rice). Elba.

Hibbertite, Heddle.-A lemon-yellow powder in kammererite ; in composition probably a mixture of magnesium hydrate and calcium carbonate. From the chromite quarry in the island of Unst, Scotland.

Hieratite, Cossa (Trans. Acad. Linc., III., vi., 14).-A potassium fluo-silicate, 2KF + $\mathrm{SiF}_{4}$, obtained in octahedral crystals from an aqueous solution of part of stalactitic concretions found at the fumaroles of the crater of Vulcano. The concretions have a grayish color, a spongy texture, rarely compact, and consist of hieratite, lamellæ of boracic acid, with selensulphur, arsenic sulphide, etc.

Homilite, Paijkull.-Near gadolinite and datolite in angles and habit. H. $=4 \cdot 5-5$. G. $=3 \cdot 34$. Lustre resinous to vitreous. Color black or blackish brown. Translucent in thin splinters. Composition $\mathrm{FeCaB}_{2} \mathrm{Si}_{2} \mathrm{O}_{10}$, or analogous to datolite. From the Stocko, near Brevig, Norway.

Hopeite.-Composition probably $\mathrm{Zn}_{3} \mathrm{P}_{2} \mathrm{O}_{8}+4$ aq. Orthorhombic. Altenberg.
Hübnerite, p. 383.-Found (Jenney) near Deadwood, Black Hills, Dakota. Also in rhodochrosite at Adervielle, in the Hautes Pyrénées.

Huntilite, Wurtz.-An impure massive mineral from Silver Islet, Lake Superior, regarded as a basic silver arsenide.

Hyalotekite, Nordenskiöld.-Coarsely crystalline, massive. H. $=5-5 \cdot 5$. G. $=3 \cdot 81$. Lustre vitreous to greasy. Color white to pearly gray. Analysis (incomplete): $\mathrm{SiO}_{2} 39.62$, $\mathrm{PbO} 25 \cdot 30, \mathrm{BaO} 20 \cdot 66, \mathrm{CaO} 7 \cdot 00$, ign. $0 \cdot 82, \mathrm{Al}_{2} \mathrm{O}_{3} \mathrm{~K}_{2} \mathrm{O}$, etc., tr. From Långban, Sweden.

Hydrocerussite, Nordenskiold.-A hydrous lead carbonate, occurring in white or colorless crystalline plates on native lead at Långban, Sweden.

Hydrofranklinite, Rœpper.-A hydrous oxide of zinc, manganese and iron, occurring in brilliant regular octahedrons, with perfect octahedral cleavage. Sterling Hill, N. J. Never completely described.

Hydrophilite,' Adam.-Calcium chloride ; see chlorocalcite, p. 260.
Hydrorhodonite, Engström.-A hydrous silicate of manganese ( $\mathrm{MnSiO}_{3}+\mathrm{aq}$ ). Massive, crystalline. Color red brown. Långban, Sweden.

Ilesite, Wuensch.-In loosely adherent crystalline aggregates. Color white. Taste bitter, astringent. Composition (M. W. Iles) $\mathrm{RSO}_{4}+4 \mathrm{aq}$, with $\mathrm{R}=\mathrm{Mn}: \mathrm{Zn}: \mathrm{Fe}=5$ : 1:1. Occurs in a siliceous gangue in Hall Valley, Park Co., Colorado.

Iodobromite, v. Lasaulx.-Isometric, octahedral. G. $=5.713$. Color sulphur yellow, sometimes greenish. Composition $2 \mathrm{Ag}(\mathrm{Cl}, \mathrm{Br})+\mathrm{AgI}$. From the mine "Schöne Aussicht," Dernbach, Nassau.

Inon, p. 226.-The later investigations of the so-called meteoric iron of Ovifak, Disco

Bay, Greenland, more especially by Törnebohm and J. Lawrence Smith, leave no doubt that it is in fact terrestrial.

Jamesonite, p. 251.-Occurs in Sevier Co., Arkansas, with other ores of antimony.
Jarosite.-Occurs in tabular rhombohedral crystals at the Vulture mine, Arizona (Silliman), and at the Arrow mine, Chaffee Co., Colorado (König). Composition $\mathrm{K}_{2} \mathrm{SO}_{4}+$ $\mathrm{Fe}_{2} \mathrm{~S}_{3} \mathrm{O}_{12}+2 \mathrm{Fe}_{2} \mathrm{H}_{6} \mathrm{O}_{6}$.

Kentrolite, Damour and vom Rath.-In minute orthorhombic crystals, grouped in sheaf-like forms like stilbite. $\mathrm{H}_{.}=5 . \mathrm{G} .=6 \cdot 19$. Color dark reddish brown. Composition probably $\mathrm{Pb}_{2} \mathrm{Mn}_{2} \mathrm{Si}_{2} \mathrm{O}_{9}$. From Southern Chili.

Krennerite, vom Rath (Bunsenin, Krenner)-Orthorhombic; in vertically striated prismatic crystals. Color silver white to brass yellow. Lustre metallic, brilliant. A telluride of gold, perhaps related to calaverite. Nagyag, Transylvania.

Lautite, Frenzel -Generally massive. $H .=3-3 \cdot 5 . \quad G=4 \cdot 96 . \quad$ Metallic. Color iron black. Formula given CuAsS, but very probably a mixture. Lauta, Marienberg, Saxony.

Lafrencite, Daubrée.-Iron protochloride occurring in the Greenland native iron, etc.
Leadhillite, p. 390.-Susannite is very probably identical with leadhillite.
Leidyite, König.-In verruciform incrustations, consisting of fine scales. Color various shades of green. A hydrous silicate of aluminum, iron, magnesium, and calcium. Leiperville, Delaware Co., Penn.

Leucite, p. 318.-Has been made artificially by Fouqué and Lévy ; also an iron leucite has been made by Hautefeuille ; optical character as of natural crystals.

Leucocifalcite, Sandberger.-In slender, nearly white crystals. According to an imperfect description, an arsenical tagilite. Wilhelmine mine in the Spessart.

Leucophantte, p. 300.-Monoclinic (Bertrand, Groth), twins analogous to those of harmotome.

Leucotile, Hare.-In irregularly grouped silky fibres of a green color. Analysis : $\mathrm{SiO}_{2}$ $28 \cdot 98, \mathrm{Al}_{2} \mathrm{O}_{3} 6 \cdot 99, \mathrm{Fe}_{2} \mathrm{O}_{3} 8 \cdot 16, \mathrm{MgO} 29 \cdot 78$, $\mathrm{CaO} 7 \cdot 37, \mathrm{Na}_{2} \mathrm{O} 1 \cdot 32, \mathrm{~K}_{2} \mathrm{O}$ tr., $\mathrm{H}_{2} \mathrm{O} 17 \cdot 29=99 \cdot 89$. Reichenstein, Silesia.

Libethenite, p. 373.-Pseudo-orthorhombic, monoclinic, according to Schrauf.
Liskeardite, Maskelyne.-Massive, incrusting. Color white. Stated to have the composition $\mathrm{Al}_{6} \mathrm{As}_{2} \mathrm{O}_{14}, 16 \mathrm{H}_{2} \mathrm{O}$. Not fully described. Liskeard, Cornwall.

Livingstonite, p. 232.-Composition probably $\mathrm{Hg}_{2} \mathrm{~S}+4 \mathrm{Sb}_{2} \mathrm{~S}_{3}$.
Louisite, Honeymann.-A transparent, glassy, leek-green mineral. H. $=6.5$ G. $=2 \cdot 41$. Analysis (H. Louis) : $\mathrm{SiO}_{2} 63.74, \mathrm{Al}_{2} \mathrm{O}_{3} 0.57$, $\mathrm{FeO} 1 \cdot 25, \mathrm{MnO}$ tr., $\mathrm{CaO} 17.27, \mathrm{MgO} 0.38$, $\mathrm{K}_{2} \mathrm{O} 3 \cdot 3 \mathrm{~S}, \mathrm{Na}_{2} \mathrm{O} 0 \cdot 08, \mathrm{H}_{2} \mathrm{O} 12 \cdot 96=99 \cdot 63$.

Macfarlanite, Sibley.-A name given to the complex granular silver ore of Silver Islet, Lake Superior, which has yielded the supposed huntilite.

Magnolite, F. A. Genth. - In radiating tufts of minute acicular crystals. Color white. Lustre silky. Composition perhaps $\mathrm{Hg}_{2} \mathrm{TeO}_{4}$. A decomposition product of coloradoite, Keystone mine, Magnolia District, Colorado.

Mallardite, Carnot.-In colorless cystalline fibrous masses. Composition $\mathrm{MnSO}_{4}+7 \mathrm{aq}$. From the "Lucky Boy" silver mine, Butterfield Cañon, near Salt Lake, Utah.

Manganosite, Blomstrand.-Isometric. Cleavage cubic. H. $=5-6$. G. $=5 \cdot 118$. Lustre vitreous Color emerald green on fresh fracture, becoming black on exposure. Composition MnO. From Långban, and from the Mossgrufva, Nordmark, Sweden.

Marmairolite. Holst.-In fine crystalline needles. H. $=5 . \quad$ G. $=3.0 \%$. Color pale yellow. Composition near enstatite, but with 6 p.c. $\mathrm{Na}_{2} \mathrm{O}$ and 1.9 p.c. $\mathrm{K}_{2} \mathrm{O}$. Långban, Sweden.

Matricite, Holst.-In crystalline masses. H. = 3-4. G. $=2 \cdot 53$. Color gray. Feel greasy. A hydrous silicate of magnesium, near villarsite, but with one molecule $\mathrm{H}_{2} \mathrm{O}$. From the Krangrufva, Wermland, Sweden.

Melanotekite, Lindström.-Massive, cleavable. H. $=6.5$. G. $=5.73$. Lustre metallic to resinous. Color black to blackish gray. Composition $\mathrm{Pb}_{2} \mathrm{Fe}_{2} \mathrm{Si}_{2} \mathrm{O}_{9}$ (analogous to kentrolite). With magnetite and yeilow garnet at Långban, Sweden.

Melanothallite, Scacchi.-Copper chloride from Vesuvius.
Melanterite, p. 395.-Luckite of Carnot is a variety containing 1.9 p.c. MnO. "Lucky Boy" silver mine, Butterfield Cañon, near Salt Lake, Utah.

Meliphanite, p. 300.-Tetragonal according to Bertrand.
Menaccanite, p. 269.-Hydroilmenite of Blomstrand is a partially altered variety, containing a little water. From Småland, Sweden.

Mica Group, pp. 311 to 315.-Tschermak has shown that all the species of the mica group are monoclinic, an axis of elasticity being inclined a few degrees to the plane of cleavage ; these conclusions are confirmed by Bauer; and von Kokscharof shows that in angle there is no sensible deviation from the orthorhombic type.

Tschermak divides the species into two groups as follows:
I.

Biotites:
Phlogopites:
Muscovites: $\left\{\begin{array}{l}\text { Lepidolite, } \\ \text { Muscovite, } \\ \text { Paragonite }\end{array}\right.$
Margarites: Margarite.
In group I. are included all the micas in which the optic axial plane is perpendicular to the plane of symmetry ; and group II. includes those in which it is parallel to the plane of symmetry. Thus, the former species biotite is divided on this principle into anomite
 example, the mica occurring with diopside in granular calcite at Lake Baikal is anomite, as also that from Greenwood Furnace, N. Y. Meroxene is represented by the Vesuvian magnesian mica. Muscovite includes also some of the "hydro-micas" to all of which belong the formula $(\mathrm{H}, \mathrm{K})_{2} \mathrm{Al}_{2} \mathrm{Si}_{2} \mathrm{O}_{8}$; phengite is a name given to some muscovites approaching lepidolite in composition, and thus not conforming to the unisilicate type. For the full discussion of the subject, see the original memoirs of Tschermak and also those of Rammelsberg, etc., referred to in Appendix III.

Haurlitonite (Heddle), from Scotch granite, etc., is a variety of biotite, characterized by containing much FeO (to 19 p.c ) and little MgO. Siderophyilite (H. C. Lewis) from Col, orado contains all $\mathrm{FeO}(25.5$ p.c.) and only a trace of magnesia.

Microlite, p. 359 -In small brilliant octahedrons, light grayish yellow to blackish brown (Nordenskiöld), at Utö, Sweden. G. $=5 \cdot 25$. Composition $\mathrm{Ca}_{2} \mathrm{Ta}_{2} \mathrm{O}_{7}$, with also MnO and MgO.

Occurs at the mica mines of Amelia Co., Virginia (Dunnington). In modified octahedrons, also in large (to 4 lbs.) imperfect crystals. G. $=5 \cdot 656$. Composition essentially $\mathrm{Ca}_{2} \mathrm{Ta}_{2} \mathrm{O}_{7}$, with also $\frac{1}{3} \mathrm{CbOF}_{3}$. Also occurs at Branchville, Conn. (Brush and Dana).

Haddamite of Shepard, from Haddam, Conn., is related, perhaps identical.
Milarite.-Orthorhombic, pseudo-hexagonal. Composition $\mathrm{HKCa}_{2} \mathrm{Al}_{2} \mathrm{Si}_{22} \mathrm{O}_{30}$. Originally described from Val Milar, but really (Kuschel) from Val Giuf, Switzerland (giufite).

Mimetite, p. 366.-According to Bertrand and Jannettaz, crystals of pure lead arsenate are biaxial; as the amount of lead phosphate increases the angle diminishes and pure lead phosphate (pyromorphite) is uniaxial ; but this may be due to the grouping of uniaxial crystals in positions not quite parallel. Occurs with vanadinite in Yuna Co., Arizona (Silliman, Blake).

Mixite, Schrauf.-Incrusting, erypto crystalline. Color emerald to bluish green. H. $=3-4$. G. $=2 \cdot 66$. A hydrous arsenate of copper and bismuth. Joachimsthal.

Molybdentte, p. 233.-Perhaps orthorhombic (Groth).
Molybdomenite, Cobaltomenite, Bertrand (Bull. Soc. Min., v. 90).-Minerals belonging to the same group of selenites as chalcomenite. Molybdomenite is a lead selenite, occurring in thin white lamellæ, nearly transparent, orthorhombic, two cleavages. Cobaltomenite is a cobalt selenite in minute rose-red crystals occurring in the midst of the selenides of lead and cobalt. From Cacheuta, Argentine Republic.

Monazite, p. 363.-From Arendal, a normal phosphate (Rammelsberg) of cerium, lanthanum and didymium, containing no thorium nor zirconium. Penfield has proved that the thorium sometimes found is due to admixed thorite. Turnerite, according to Pisani, has the same composition.

Occurs in very brilliant highly modified crystals at Milholland's Mill, Alexander Co., N. C.; also at other localities in North Carolina (Hidden). In large masses with microlite at the mica mines of Amelia (\%., Va.; also at Portland (near Middletown) Conn.

Monetite, C. U. Shepard and C. U. Shepard, Jr.-In irregular aggregates of small triclinic crystals. H. $=3 \cdot 5$. G. $=2.75$. Lustre vitreous. Color pale yellowish white. Semitransparent. Composition $\mathrm{HCaPO}_{4}$, requiring $\mathrm{P}_{2} \mathrm{O}_{5} 52 \cdot 20$, $\mathrm{CaO} 4.1 \cdot 18, \mathrm{H}_{2} \mathrm{O} .6 \cdot 62=100$. Occurs with gypsum and monite at the guano islands, Moneta and Mona, in the West Indies.

Monite occurs as a slightly coherent, uncrystalline, snow-white mineral. G. $=2 \cdot 1$. Composition perhaps $\mathrm{Ca}_{3} \mathrm{P}_{2} \mathrm{O}_{8}+\mathrm{H}_{2} \mathrm{O}$.

Mordente.-Steeleite of How is an altered mordenite from Cape Split, N. S. Mordenite (How) has the composition $\mathrm{SiO}_{2} 68 \cdot 40, \mathrm{Al}_{2} \mathrm{O}_{3} 12 \cdot 7 \%$, (aO $3 \cdot 46, \mathrm{Na}_{2} \mathrm{O} 2 \cdot 35, \mathrm{H}_{2} \mathrm{O}$ $13 \cdot 02=100$.

Nagyagite, p. 249.-Perhaps orthorhombic (Schrauf).
Natrolite, p. 342.-Monoclinic, according to Lüdecke.
Neocyanite, Scacchi.-In minute tabular crystals of a blue color. Supposed to be an anhydrous copper silicate. Mt. Vesuvius.

Nephrite, p. 297. -The general subject of nephrite and jadeite in their mineralogical and archæological relations has been exhaustively discussed by Fischer in a special work on that subject.

[^54]Nitrobarite. - Crystals of native barium nitrate have been obtained from Chili; in apparent octahedrons formed of the two tetrahedrons.

Nocerine, Scacchi. - In white acicular crystals, perhaps rhombohedral ; regarded as a double fluoride of calcium and magnesium. From the volcanic bombs of Nocera.

Octahedrite (Anatase), p. 27\%.-Belongs to the monoclinic system, according to Mallard's view (see p. 186).

Found in nearly colorless transparent crystals at Brindletown, Burke Co., N. C. (Hidden).
Onofrite.-A massive mineral (G. $=7 \cdot 62$ ), from Marysvale, Utah, has the composition $\mathrm{Hg}(\mathrm{S}, \mathrm{Se})$, with $\mathrm{S}: \mathrm{Se}=6: 1$. It thus corresponds nearly with Haidinger's onofrite, which has $\mathrm{S}: \mathrm{Se}=4: 1$.

Orpinent (p. 231) and realgar (p. 231) occur in Iron Co., Utah (Blake).
Orthoclase, p. 325.-Klockmann (Z. Kryst., vi., 493) has described twins of orthoclase from the Scholzenberg, near Warmbrunn, in Silesia, the twinning planes in different cases were $i-i, O, 2-i, 2-i, I$. $i-\overline{3}$.

Orthite, p. 308.-Found in imperfect bladed crystals at the mica mines in Amelia Co., Virginia, with monazite, columbite, etc.

Ottrelite, p. 358.-A variety of ottrelite from Vénasque, in the Pyrenees, has been called venasquite (Damour).

Oxamite.-Ammonium oxalate (Shepard) from the Guanape Islands. Also called guanapite by Raimondi.

Ozocerite.-A related mineral wax has been found in large quantities in Utah.
Pachnolite, p. 265.-See thomsenolite, p. 438.
Peckhamite, J. Li. Smith.-From the Estherville, Emmet Co., Iowa, meteorite. In rounded nodules, with greasy lustre, and light greenish-yellow color. G. $=3 \cdot 23$. Compcsition equivalent to two molecules of enstatite and one of chrysolite.

Pectolite, p. 337.-Walkerite (Heddle) is a closely related mineral from the Corstorphine Hill, near Edinburgh, Scotland.

Pelagite, Church.-A name given to the composite manganese nodules obtained by the "Challenger" from the bottom of the Pacific.

Penwithite, Collins.-Described as a hydrated silicate of manganese ( $\mathrm{MnSiO}_{3}+2 \mathrm{aq}$ ) from Penwith, Cornwall.

Perofskite, p. 270.-Recent observations refer it to the orthorhombic system, the crystals being complex twins. Ben-Saude, however, regards it as isometric and parallel hemihedral, the observed double refraction being due to secondary causes, see p. 190.

Petalite, p. 295.-Hydrocastorite is an alteration product of castorite from Elba (Grattarola).

Pharmacosiderite, p. 376.-Pseudo-isometric, according to Bertrand, see p. 186.
Phenacite, p. 301.-Obtained well crystallized from Switzerland, perhaps from Val Giui. Also (Cross and Hillebrand) from near Pike's Peak, El Paso Co., Colorado.

Phillipsite, p. 345.-Crystalline system monoclinic (Streng), with a higher degreo of pseudo-symmetry due to twinning.

Phosphuranylite, Genth.-As a pulverulent incrustation, of deep lemon-yellow color. Composition probably $\left(\mathrm{UO}_{2}\right)_{3} \mathrm{P}_{2} \mathrm{O}_{8}+6$ aq. Occurs with other uranium minerals at the Flat Rock mine, Mitchell Co., N. C.

Picite, Nies.--An amorphous, dark brown hydrous iron phosphate from the Eleonore mine and the Rothläufchen mine, near Giessen. Of doubtful homogeneity.

Pickeringite, p. 395.-Sonomaite (Goldsmith), from the Geysers, California, and picroallumogene (Roster), from Elba, are closely related minerals.

Pilolite, Heddle. - A name suggested for some minerals from Scottish localities of nearly related composition, which have gone by the names " mountain leather" and 'mountain cork."

Plagiocitrite, Sandberger, Singer.-A hydrous sulphate of alumina, iron, potassium, sodium, etc., occurring in lemon-yellow microscopic crystals, and formed from the decomposition of pyrite at the Bauersberg, near Bischofsheim vor der Rhön.

Platinum, p. 223.-A nugget weighing 104 grams, and consisting of 46 p.c. platinum and 54 p.c. chromite, was found near Plattsburgh, N. Y. (Collier).

Plumbonanganite, Hannay.-Described as a sulphide of manganese and lead, but doubtless a mixture. Source unknown.

Plumbostannite, Raimondi.-An impure massive mineral, described as a sulph-antimonite of tin, lead and iron, but of doubtful homogeneity. From the district of Moho, Peru.

Polydymite, Laspeyres. -Isometric, octahedral. H. $=4 \cdot 5$. G. $=4 \cdot 808-4 \cdot 816$. Composition $\mathrm{Ni}_{4} \mathrm{~S}_{5}$. From Grünau, Westphalia. Laspeyres regards the saynite of von Kobell, grünauite of Nicol, as an impure polydymite.

Polyhalite, p. 393.-Krugite (Precht) is a related mineral from New Stassfurt. Composition, if homogeneous, $\mathrm{K}_{2} \mathrm{SO}_{4}+\mathrm{MgSO}_{4}+4 \mathrm{CaSO}_{4}+2$ aq.

Priceite, p. 382.-Pandermite (vom Rath) is a borate from Panderma on the Black Sea, near priceite, if not identical with it.

Pseudobrookite, Koch.-In thin tabular striated crystals, orthorhombic. H. $=6$. G. $=4.98$. Lustre adamantine, on crystalline faces. Color dark brown to black. Contains principally the oxides of iron and titanium. From the andesite of the Aranyer Berg, Transylvania, and Riveau Grand, Monte Dore, also with the asparagus stone of Jumilla, Spain (Lewis). Near brookite.

Pseudonatrolite, Grattarola.-In minute acicular crystals. Colorless. A hydrous silicate ( $62 \cdot 6$ p.c. $\mathrm{SiO}_{2}$ ) of aluminum and calcium. From San Piero, Elba.

Psilomelane, p. 282.-Calvonigrite (Laspeyres) from Kälteborn is a variety.
Pyrite, p. 243.-Occurs in highly modified crystals in Gilpin Co., Colorado.
Pyrolusite, p. 2i8.-According to Groth, the prismatic angle is $99^{\circ} 30^{\prime}$.
Pyrophosphorite. C. U. Shepard. Jr.-A massive, earthy, snow-white mineral from the West Indies. Described as a pyrophosphate of calcium and magnesium.

Pyrrhotite, p. 241.-Perhaps only pseudo-hexagonal, the apparent form due to twinning.

Quaktz, p. 284.-The smoky quartz of Branchville, Conn., contains very large quantities of liquid $\mathrm{CO}_{2}$ (Hawes), also $\mathrm{N}, \mathrm{H}_{2} \mathrm{~S}, \mathrm{SO}_{2}, \mathrm{H}_{3} \mathrm{~N}, \mathrm{~F}$ (A. W. Wright).

Ralstonite, p. 265.-Composition (Brandl) $\left.3 \backslash \mathrm{Na}_{2}, \mathrm{Mg}, \mathrm{Ca}\right) \mathrm{F}_{2}+8 \mathrm{Al}_{2} \mathrm{~F}_{6}+6 \mathrm{H}_{2} \mathrm{O}$.
Randite, König. - A canary yellow incrustation on granite at Frankford, near Philadelphia. Contains calcium and uranium, but composition doubtful.

Reddingite, G. J. Brush and E. S. Dana.-Orthorhombic ; habit octahedral ; form near that of scorodite. H. $=3-3 \cdot 5$. G. $=3 \cdot 10$. Lustre vitreous to sub-resinous. Color pale rose pink to yellowish white. Composition $\mathrm{Mn}_{3} \mathrm{P}_{2} \mathrm{O}_{8}+3 \mathrm{aq}$, with a varying amount of iron ( $5-8$ p.c. FeO ). With other manganesian phosphates at Branchville, Conn.

Reinite, K. v. Fritsch, Lüdecke.-A tetragonal iron tungstate ( $\mathrm{FeWO}_{4}$ ) near scheelite in form, and perhaps a pseudomorph. From Kimbosan, Japan.

Resin.-The following are names recently given to various hydrocarbon compounds : ajkite, bernardinite, celestialite, duxite, gedanite, hofmannite, huminite, ionite, köflachite, muckite, neudorfite, phytocollite, posepnyte.

Rhabdophane, Lettsom.-A cerium phosphate, perhaps the same as phosphocerite.
Rhopochrosite, p. 403.-A Hungarian variety, containing 39 p.c. $\mathrm{FeCO}_{3}$, has been called manganosiderite (Bayer).

Occurs at Branchville, Conn., containing $16 \cdot 76$ p.c. FeO (Penficld).
Rhodizite.-According to Damour, rhodizite of Rose, from the Ural, is an alkaline boroaluminate. Pseudo-isometric according to Bertrand.

Rogersite, J. L. Smith.-A thin mammillary crust, of a white color, on samarskite. A hydrous columbate of yttrium, etc., exact composition undetermined. Mitchell Co., N. C.

Roscoeeite, p. 367.-A silicate, according to recent analyses by Genth, having the formula $\mathrm{K}(\mathrm{Mg}, \mathrm{Fe})\left(\mathrm{Al}_{2}, \mathrm{~V}_{2}\right)_{2} \mathrm{Si}_{12} \mathrm{O}_{32}+4 \mathrm{aq}$; also (Hanks) from Big Red Ravine, near Sutter's Mill, Cal.

Roselite, p. 572 .-True composition $\mathrm{R}_{3} \mathrm{As}_{2} \mathrm{O}_{8}+2 \mathrm{aq}$ (Winkler), hence analogous to fairfieldite, p. 426.

Rubislite, Heddle.-An uncertain chloritic substance from the granite of Rubislaw, near Aberdeen, Scotland.

Rutile, p. 276.-Pseudo-tetragonal according to the view of Mallard (see p. 186).
Occurs in splendent crystals in Alexander Co., N. C. (Hidden).
Samarskite, p. 361.-The North Carolina mineral has been shown to contain erbium, terbium, phillipium, decipium (Delafontaine, Marignac). A supposed new element, mosandrum, was also announced by Smith. Vietinghofite is a ferruginous variety from Lake Baikal, in the Ural.

Sarawaitite, Frenzel.-Occurs in miaute crystals in the native antimony of Borneo; perhaps senarmontite.

Scapolite, p. 317.-The scapolites have been shown by Adams to contain chlorine (up to $2 \cdot 48$ p.c.) when quite unaltered. The analyses of Neminar, Sipöcz, and Becke prove the same.

Ontariolite (Shepard) is a variety occurring in limestone at Galway, Ontario, Canada.
Schneebergite, Brezina.-In isometric octahedrons of a honey-yellow color from Schneeberg, Tyrol. Contains lime and antimony, but exact composition unknown.

Schorlomite, p. 337.-The so-called schorlomite of the Kaiserstuhl is, according to Knop, either a titaniferous melanite or pyroxene.

Semseyite, Krenner.-Stated to be related to plagionite ; from Felsöbanya. Not yet described.

Senarmontite, p. 284. - Pseudo-isometric according to Mallard (p. 186). Grosso-Bohle, who has investigated the subject, suggests the same for arsenolite.

Sepiolite, p. 349.-Chester has analyzed a fibrous variety from Utah.
Serpentine, p. 350.-Schrauf (Z. Kryst., vi.. 321) has studied the magnesia silicates from the serpentine region near Budweis, Southern Bohemia. He introduces the following new names : Kelyphite, a serpentinous coating of altered crystals of pyrope ; Enophite, a chloritic variety of serpentine ; Lernilitc (wrong orthography for lennilite) in composition near the vermiculite of Lenni (Cooke), hence name ; Siliciophite, a heterogeneous substance high in silica; Hydrobiotite (same name used by Lewis) a hydrated biotite ; Berlauite, a chloritic substance filling cavities between the granite and serpentine ; Schuchardtite, the so-called chrysopraserde from Gläsendorf, Silesia. He also uses the general name parachlorite for substances conforming to $m \mathrm{Al}_{2} \mathrm{Si}_{3} \mathrm{O}_{12}+n \mathrm{R}_{2} \mathrm{SiO}_{4}+p \mathrm{aq}$, and protochlorite for those corresponding to $m \mathrm{Al}_{2} \mathrm{SiO}_{5}+n\left(\mathrm{R}_{2} \mathrm{SiO}_{4}\right)+p$ aq.

Totaigite (Heddle) is an uncertain serpentinous mineral, derived from the decomposition of malacolite. From Totaig, Rosshire, Scotland.

Serpierite, Des Cloizeaux.-In minute tabular crystals; o.thorhombic. Color greenish. Stated to be a basic sulphate of copper (Damour). From Laurium, Greece.

Siderazot, Silvestri.-Iron nitride, a coating on lava at Etna.
Sideronatrite, Raimondi.-Sideronatrite, from Huantajaya, Peru, and urusite (Frenzel) from the island Tschleken, Caspian Sea, are hydrous sulphates of iron and sodium, near each other and related to the doubtful bartholomite.

Sipylite, Mallet.-Tetragonal, in octahedrons. Form near that of fergusonite. Cleavage octahedral; usually massive, crystalline. $\quad \mathrm{H}=6 . \quad \mathrm{G} .=4 \cdot 89$. Color brownish black to brownish orange. Essentially a columbate of erbium, cerium, lanthanum, didymium, uranium, etc. With allanite on the Little Friar Mt., Amherst Co., Va.

Smaltite, p. 245.-Occurs near Gothic, Gunnison County, Colorado.
Spherocobaltite, Weisbach.-In small spherical masses, concentric, radiated. Color within rose-red. $\mathrm{H} .=4 . \quad \mathrm{G} .=4 \cdot 02-4 \cdot 13$. Composition $\mathrm{CoCO}_{3}$. With roselite at Schneeberg, Saxony.

Spodiosite, Tiberg.-In flattened prismatic crystals. A calcium phosphate, and perhaps pseudomorphous. From the Krangrufra, Wermland, Sweden.

Sphalerite, p. 237.-The sphalerite from the Pierrefitte mine, Vallée Argelès, Pyrénées, contains gallium (L. de Boisbaudran), and various American (Cornwall) and Norwegian (Wleugel) varieties afford indium.

Spodumene, p. 295.-The true composition is expressed by the formula $\mathrm{Li}_{2} \mathrm{Al}_{2} \mathrm{Si}_{4} \mathrm{O}_{12}$, as proved by numerous recent anaiyses.

Occurs in small prismatic crystals of a deep emerald green to yellowish green color, with beryl (emerald), rutile, monazite, etc., in Alexander Co., N. C. This variety, which has been extensively introduced as a gem, was called hiddenite by J. L. Smith, after W. E. Hidãen.

The alteration products of the spodumene of Chesterfield and Goshen, Mass., have been described by A. A. Julien.

Occurs in immense crystals at Branchville, Conn. (Brush and Dana). The unaltered mineral is of an amethystine purple color and perfectly transparent, but the crystals are mostly altered. This alteration has yielded (1) a substance called $\beta$-spodumene, apparently homogeneous, but in fact an intimate mixture of albite and eucryptite (q.v., p. 426); also cymatolite, a mixture of albite and muscovite ; also albite alone; muscovite ; microcline, and killinite.

Staurolite, p. 336.-Xantholite (Heddle) from near Milltown, Loch Ness, Scotland, is a closely related mineral.

Sternbergite, p. 240.-Argentopyrite, Argyropyrite and Frieseite are varieties, or at least closely related minerals. They are essentially identical in form. while Streng shows that the composition of the series may be expressed by the general formula $\mathrm{Ag}_{2} \mathrm{~S}+$ $p \mathrm{Fe}_{n} \mathrm{~S}_{n+1}$ 。

Stiblanite, Goldsmith.-A doubtful decomposition product of stibnite, near stibiconite. From Victoria.

Stibiconite.-Extensive deposits of an antimony oxide, near stibiconite, occur at Sonora, Mexico. The ore carries silver chloride.

Stibnite, p. 232.-Occurs with other antimony minerals in Sevier Co., Arkansas. In groups of large splendent crystals on an island in western Japan.

Stilbite, p. 346.- Monoclinic, and isomorphous with harmotome and phillipsite (v. Lasaulx).

Strengite, Nies.-Orthorhombic, and isomorphous with scorodite. Generally in spherical and botryoidal aggregates. H. $=3-4 . \quad \mathrm{G} .=287$. Lustre vitreous. Color various shades of red to colorless. Composition $\mathrm{Fe}_{2} \mathrm{P}_{2} \mathrm{O}_{8}+4$ aq. From the Eleonore mine near Geissen, the Rothläufchen mine near Waldgirmes ; also in cavities in the dufrenite from Rockbridge Co., Va. (König).

Strontianite, p. 406.-Occurs at Hamm, Westphalia, sometimes in highly modified pseudo-hexagonal crystals, resembling common forms of aragonite (Laspeyres).

Stützite, Schrauf.-A silver telluride, occurring in pseudo-hexagonal crystals of a lead gray color. Named from a single specimen probably from Napyag.

Szaboite, Koch.-In minute triclinic crystals, near rhodonite in form. H. =6-7. G. $=3.505$. Lustre vitreous ; sometimes tending to metallic and pearly. Color hair brown ; in very thin translucent crystals brownish red. A silicate of calcium and iron ( $\mathrm{RSiO}_{3}$ ) related to babingtonite. Occurs with pseudobrookite in the andesite of the Aranyer Berg, Transylvania; Mt. Calvario, Etna; Riveau Grand, Monte Dore.

Szmikite, v. Schröckinger.-Amorphous, stalactitic. Color whitish to reddish. Composition $\mathrm{MnSO}_{4}+\mathrm{H}_{2} \mathrm{O}$. Felsöbanya, Transylvania.

Talktriplite (Igelström).-A phosphate of iron, manganese, magnesium and calcium ; probably a triplite remarkable as containing MgO ( $17 \cdot 42$ p.c.) and CaO (14.91). From Horrsjöberg in Wermland, Sweden.

Tantalite, p. 359.-Occurs in North Carolina; in Coosa Co., Ala.
Mangantantalite (Nordenskiold) is a manganesian variety ( 9 p.c. MnO) from Utö, Sweden.
Tarapacaite, Raimondi.-A supposed potassium chromate, occurring in bright yellow fragments in the midst of the soda nitre from Tarapaca, Peru.

Taznite, Domeyko.-Regarded as an arsenio-antimonate of bismuth, but probably a heterogeneous substance.

Tellurite. - The tellurium oxide $\left(\mathrm{TeO}_{2}\right)$ occurs in minute prismatic, yellow to white crystals, imbedded in native tellurium ; also incrusting. Keystone, Smuggler and John Jay mines in Colorado.

Tellurium, p. 227.-An impure variety from the Mountain Lion mine, Colorado, has been called Lionite.

Tennantite, p. 256.-Fredricite (H. Sjögren) is a variety from Falu, Sweden, containing lead (3 p.c.), tin ( $1 \cdot 4$ p.c.) and silver ( $2 \cdot 9$ p.c.).

Tenorite, p. 267.-Made triclinic, on optical grounds, by Kalkowsky.
Tequesquite.-A corruption of tequixquitl, a name used in Mexico to designate a mixture of different salts.

Tetrahedrite, p. 255.-Occurs near Central City, Gilpin Co., Colorado, in crystals coating chalcopyrite in parallel position. Also at Newburyport, Mass. ; in Arizona (16:23 p.c. Pb ).

Frigidite (D'Achiardi) is a variety with 12.7 p.c. Fe, etc., from the Valle del Frigido, Apuan Alps.

Thaumasite, Nordenskiöld.-Massive, compact. H. $=3 \cdot 5$. G. $=1 \cdot 87 \%$. Color white. Lustre greasy, dull. Composition deduced $\mathrm{CaSiO}_{3}+\mathrm{CaCO}_{3}+\mathrm{CaSO}_{4}+14$ aq, but it is very doubtful whether the material analyzed was homogeneous.

Thenardite, p. $890 .-O c c u r s$ in large deposits on the Rio Verde, Arizona (Silliman).
Thomsenolite, p. 265.-According to Klein and, later, Brandl and Groth, thomsenolite and pachnolite are distinct minerals. Thomsenolite is monoclinic, $\beta=89^{\circ} 37 \frac{1_{2}^{\prime}}{}$, and $c$ (vert.) : $b: \grave{a}=1 \cdot 0877: 1: 09959$, and has the composition $(\mathrm{Na}+\mathrm{Ca}) \mathrm{F}_{3}+\mathrm{Al}_{2} \mathrm{~F}_{6}+\mathrm{H}_{2} \mathrm{O}$. Pachnolite is monoclinic, $\beta=89^{\circ} 40^{\prime}, c$ (vert.) $: b: \grave{a}=1 \cdot 5320: 1: 1626$, and has the composition $(\mathrm{Na}+\mathrm{Ca}) \mathrm{F}_{3}+\mathrm{Al}_{2} \mathrm{~F}_{6}$. Pachnolite is a cryolite with two sodium atoms replaced by one calcium atom, and thomsenolite is the same, with also one molecule of water.

Thomsonite, p. 342.-Occurs in amygdules in the diabase of Grand Marais, Lake Superior ; also in polished pebbles on the lake shore. The pebbles are sometimes opaque white, like porcelain ; sometimes green in color and granular (variety called lintonite) ; sometimes with fibrous radiated structure, of various colors, and of great beauty. The last are valued as ornaments.

Thinolite.-Calcium carbonate, forming large tufa-like deposits in Nevada, a shore formation of the former Lake Lahontan. Regarded by King as pseudomorph after gaylussite, but this is doubtful.

Thorite, p. 340.-A variety of thorite is called uranothorite by Collier ; it contains $9 \cdot 96 \mathrm{U}_{2} \mathrm{O}_{3}$. Massive. G. $=4 \cdot 126$. Color dark red-brown. From the Champlain iron region, N. Y.

Titante, p. 335.- Occurs, often in enormous crystals or groups of crystals, at Renfrew, Canada, with zircon (twins), apatite and amphibole.

Alshedite (Blomstrand) is a variety from Småland, Sweden, containing 2.8 p.c. YO.
Titanomorphite is a name given by v. Lasaulx to a part of the white granular aggregates surrounding rutile and menaccanite, and derived from their alteration. It is a calcium titanate, according to Bettendorff's analysis, but Cathrein (Z. Kryst., vi., 244) shows that it is really a variety of titanite. Leucoxene is a name earlier (13\%4) given by Gümbel for a similar substance of doubtful chemical nature often observed in rocks; according to Cathrein it is a titanite with or without a mixture of rutile microlites.

Topaz, p. 332.-Pseudo-orthorhombic (monoclinic), according to the view of Mallard (see p. 186).

Occurs near Pike's Peak, El Paso Co., Colorado, and at Stoneham, Maine.
Torbanite, p. 418.-Wollongongite (p. 416) is referred to torbanite by Liversidge ; it is from Hartley, New South Wales, not Wollongong, so that the name is inappropriate.

Tourmaline, p. 329.- Pseudo-rhombohedral. according to the view of Mallard (see p. 186).

Occurs in white, nearly colorless crystals, at De Kalb, St. Lawrence Co., N. Y.

Tridymite, p. 288.-Pseudo-hexagonal (triclinic), according to Schuster and also v. Lasaulx. Asmanite is probably identical with it.

Hantefeuille has made it artificially; and it has been observed with zine spinel as a result of the alteration of zinc muffles.

Triphylite, p. 369.-The composition (Penfield) is $\mathrm{LiFePO}_{4}=\mathrm{Li}_{3} \mathrm{PO}_{4}+\mathrm{Fe}_{3} \mathrm{P}_{2} \mathrm{O}_{8}$, with the iron replaced by manganese in part.

Lithiophilite (Brush and Dana) is' a variety almost free from iron (down to 4 p.c.), and corresponding to the formula $\mathrm{LiMnPO}_{4}=\mathrm{Li}_{3} \mathrm{PO}_{4}+\mathrm{Mn}_{3} \mathrm{P}_{2} \mathrm{O}_{8}$. Massive, cleavable (O.I, $i-\imath$ ). Color salmon,-honey yellow, yellowish brown, light clove brown. Occurs with other manganesian phosphates in pegmatite, at Branchville, Fairfield Co., Conn.

Triploidite (G. J. Brush and E. S. Dana).-Monoclinic, near wagnerite in form. Generally in fibrous crystalline aggregates. H. $=4 \cdot 5-5$. G. $=3 \cdot 697$. Lustre vitreous to greasy adamantine. Color yellowish to reddish brown. topaz yellow, hyacinth red. Transparent. Composition $\mathrm{R}_{3} \mathrm{P}_{2} \mathrm{O}_{8}+\mathrm{R}(\mathrm{OH})_{2}$. with $\mathrm{R}=\mathrm{Mn}: \mathrm{Fe}=3: 1$; hence analogous to triplite, but with $(\mathrm{OH})$ replacing F . With other manganesian phosphates (eosphorite, lithiophilite, etc.) from Branchville, Conn.

Trippkette, Damour and vom Rath.-In small brilliant crystals, tetragonal. Color bluish green. Stated to be a hydrous arsenite of copper. With olivenite in cuprite from Copiapo, Chili.

Tysonite, Allen and Comstock.-Hexagonal. Cleavage basal. H. $=4 \cdot 5-5 . \quad$ G. $=6 \cdot 13$. Lustre vitreous to resinous. Color pale wax yellow. Composition ( $\mathrm{Ce}, \mathrm{La}, \mathrm{Di})_{2} \mathrm{~F}_{6}$. From near Pike's Peak, ('olorado. The crystals are mostly altered to bastnäsite (also called hamartite), which is a fluo-carbonate, near parisite.

Uraninite, p 274.-Occurs in brilliant black octahedral crystals at Branchville, Conn. $\mathrm{G}=9 \cdot 2 \overline{5}$. Analysis: $\mathrm{UO}_{3} 40 \cdot 08, \mathrm{UO}_{2} 54.51, \mathrm{PbO} 4 \cdot 27, \mathrm{FeO} 0 \cdot 49, \mathrm{H}_{2} \mathrm{O} \quad 0 \cdot 88=100 \cdot 23$. Also from Mitchell Co., N. C.; mostly altered to gummite.

Uranocircite, Weisbach.-Orthorhombic, like autunite. Cleavage basal perfect. G. = 3.53. Color yellow green. Composition $\mathrm{BaU}_{2} \mathrm{P}_{2} \mathrm{O}_{12}+8$ aq. In quartz veins, Saxon Voightland.

Uranothallite, Schrauf (Z. Kryst., vi., 410).-A uranium carbonate from Joachimsthal, originally mentioned by Vogl. Occurs in confused aggregates of orthorhombic crystals. Calculated formula $\mathrm{UC}_{2} \mathrm{O}_{6}+2 \mathrm{CaCO}_{3}+10$ aq.

Uranotile, p. 341.-Occurs in Mitchell Co., N. C. Genth writes the formula, $\mathrm{Ca}_{3}\left(\mathrm{UO}_{2}\right)_{6} \mathrm{Si}_{6} \mathrm{O}_{21}+18$ aq.

Vanadinite, p. 367.-Occurs in highly modified crystals in the State of Cordoba, Argentine Republic. Also in very beautiful ruby-red crystals at the Hamburg and other mines in Yuma Co., Arizona (Silliman; Blake), and in yellow to nearly white crystals at other localities in Arizona.

Variscite.-The so-called peganite from Montgomery Co., Ark., is shown by Chester to be identical with Breithaupt's variscite. Composition $\mathrm{Al}_{2} \mathrm{P}_{2} \mathrm{O}_{8}+4$ aq.

Venerite, Hunt.-An impure chloritic mineral containing copper ; mined as copper ore at Jones' mine, near Springfield, Berks Co., Penn.

Vermiculite, p. 3n5.-Protovermiculite (König) and philndelphite (Lewis) are minerals related to the other "vermiculites," the whole group being decomposition products of other micas.

Vesbine, Scacchi.-Forms thin yellow crusts on lava of 1631, Vesuvius; supposed to contain a new element, vesbium.

Vesuvianite, p. 405.-Pseudo-tetragonal, according to the view of Mallard (see p. 186). A variety from Jordansmühl contains 3 p.c. MnO (manganidocrase).

Veszelyite, p. 373.-Composition, according to Schrauf, $2(\mathrm{Zn}, \mathrm{Cu})_{3} \mathrm{As}_{2} \mathrm{O}_{8}+9(\mathrm{Zn}, \mathrm{Cu}) \mathrm{H}_{2} \mathrm{O}_{2}$ +9 aq, with $\mathrm{Cu}: \mathrm{Zn}=3: 2$, and $\mathrm{As}: \mathrm{P}=1: 1$.

Wad, p. 283.-Lepidophceite (Weisbach) is a related mineral from Kamsdorf, Thuringia. Composition stated to be $\mathrm{CuMn}_{6} \mathrm{O}_{12}+9$ aq.

Wagnerite, p. 368.-Kjerulfine has been shown to be identical with wagnerite in form and composition ; often partially altered.

Walpurgite, p. 379.-Triclinic (pseudo-monoclinic), according to Weisbach.
Wattevillite, Singer.-In minute acicular snow-white crystals. A hydrous sulphate of calcium, sodium, potassium, etc. Formed from the decomposition of pyrite at the Bauersberg, near Bischofsheim vor der Rhön.

Wulfente; p. 384--Occurs in fine crystals in the Eureka district, Nevada; also in Yuma Co., Arizona, sometimes in simple octahedral crystals (Silliman).

Xanthophylitee, p. 358.-Waluewite (v. Kokscharof) is a well crystallized variety from Achmatovsk, Ural.

Xenotime, p. 364.-Occurs compounded with zircon in Burke Co., N. C. (Hidden).
Youngite, Hannay. - Described as a sulphide of lead, zinc, iron and manganese, but doubtless a mixture.

Zincaluminite, Bertrand and Damour. - In thin hexagonal plates minute. H. $=2 \cdot 5-3$. G. $=2 \cdot 26$. Composition $2 \mathrm{ZnSO}_{4}+4 \mathrm{ZnH}_{2} \mathrm{O}_{2}+3 \mathrm{Al}_{2} \mathrm{H}_{6} \mathrm{O}_{6}+5 \mathrm{aq}$. From the zinc mines of Laurium, Greece.

Zircon, p. 304.-Occurs in fine twin crystals ( $1-i$, like rutile and cassiterite) with titanite and apatite, in Renfrew Co., Canada (Hidden). Also with astrophyllite and arfvedsonite in El Paso Co., Colorado.

Pseudo-tetragonal, according to the view of Mallard (see p. 186).
Beccarite (Grattarola) is a variety from Ceylon.

## APPENDIX A.

## SYNOPSIS OF MILLER'S SYSTEM OF CRYSTALLOGRAPHY.

The following pages contain a concise presentation of the System of Crystallography proposed by Prof. W. H. Miller in 1839, and now employed by a large proportion of the workers in Mineralogy. The attempt has been made to present the subject briefly, and yet with sufficient fulness to enable any one having some previous knowledge of Crystallography not only to understand the System, but also to use it himself. For the full development of the subject, especially of its theorotical side, reference must be made to the works of Miller, Grailich, von Lang, Schrauf and Bauerman (see the Introduction), as also to the admirable Lectures of Prof. Maskelyne, printed in the Chemical News for 1873 (vol. xxxi., 3, 13, 24,63, 101, 111, 121, 153, 200, 232).

## General Principles.

The indices of Miller and their relation to those of Naumann.-The position of a plane ABC (f. 751) is determined when the distances OA, OB, OC are known, which it cuts off in the

assumed axes $\mathrm{X}, \mathrm{Y}, \mathrm{Z}$ from their point of intersection $\mathbf{O}$. The lengths of these axes for a single plane of a crystal being taken as units, thus $\mathrm{OA}=a, \mathrm{OB}=b, \mathrm{OC}=\dot{c}$, it is found that the lengths of the corresponding lines $\mathrm{OH}, \mathrm{OK}$, OL for any other plane, HKL, of the same crys-
tal always bear some simple relation, expressed in whole numbers, to these assumed units This relation may be expressed as follows:

$$
\frac{a}{\mathrm{OH}}=h \quad \frac{b}{\mathrm{OK}}=\hbar \quad \frac{c}{\mathrm{OL}}=l
$$

or in the more common form

$$
\begin{equation*}
\frac{1}{h} \cdot \frac{a}{\mathrm{OH}}=\frac{1}{k} \cdot \frac{b}{\mathrm{OK}}=\frac{1}{b} \cdot \frac{c}{\mathrm{OL}}=1 \tag{1}
\end{equation*}
$$

The numbers represented by $h, k, l$ are called the indices of the plane and determine its position, when the elements of the crystal-the lengths and mutual inclinations of the axesare known. When the lines are taken in the opposite direction from O , they are called negative; the corresponding negative character of the indices is indicated by the minus sign placed over the index, thus, $\bar{\hbar}, \bar{\hbar}$, or $l$. When the unit, or fundamental form, is appropriately chosen, the numbers representing $h, k, l$ seldom exceed six.

The above relation may also be written in the form :

$$
\frac{\mathrm{OH}}{a}=r \quad \frac{\mathrm{OK}}{b}=n \quad \frac{\mathrm{OL}}{c}=m .
$$

Here $r, n, m$, which are obviously the reciprocals of the indices $h, k, l$ respectively, are essentially identical with the symbols of Naumann. For example, if $h=3, k=2, l=2$, then $r=\frac{1}{8}, n=\frac{1}{2}, m=\frac{1}{2}$, and the symbol (322) of Miller becomes $\frac{1}{8} a: \frac{1}{2} b: \frac{1}{2} \dot{c}$; but by Naumann's usage this is so transformed that $r=1$, and $n>1$ (or sometimes $n=1$, and $r>1$ ), in other words, by multiplying through by 3 , in this case, the symbol takes the form $a: \frac{3}{2} b$ : $\frac{3}{2} c, *$ or, as abbreviated, $\frac{2}{2}-\frac{5}{2}\left(\frac{3}{2} \mathrm{P}_{\frac{3}{2}}^{3}\right)$. The symbol $a: \frac{3}{2} b: \frac{3}{2} c$ properly belongs to the plane MNR (f. 751), which is parallel to, and hence crystallographically identical ( p .11 ) with the plane HKL.

Special values of the indices $h, k, l$. It is obvious that several distinct cases are possible : (1) The three indices $h, k, l$ are all greater than unity, then including the various pyramidal planes. The number of similar planes corresponding to the general form $\{k l l\}$ depends upon the degree of symmetry of the crystalline system, and upon the special values of $h, k, \eta$, e.g., $h=k$, etc. These cases are considered later in their proper place.
(2) One of the three indices may be equal to zero, indicating then that the plane is parallel to the axis corresponding to this index. Thus the symbol $(h k 0),=a: n b: \infty c$, or $n a: b: \infty c$ ( $\mathbf{p} .11$ ), belongs to the planes parallel to the vertical axis $c$, as shown in f. 752. They are called prismatic planes. The symbol ( $h 0 l$ ) $=a: \infty b: m c$ (p. 11) belongs to the planes parallel to the axis $b$, as in f. 753. The symbol $(0 k l),=\infty a: b: m c$, belongs to the planes paralle] to the axis $a$, f. 754 .

(3) Two of the indices may be zero, the symbol ( $k k l$ ) then becomes (001), $=\infty \pi$. $\infty$ o $b: s$, the basal plane, f. $75 \overline{5} ;(010),=\infty a: b: \infty c$; and $(100),=a: \infty b: \infty c$. These are the three diametral or pinacoid planes.

The symbol (010) represents the clinopinacoid ( $i-i$ ) of the Monoclinic system, and (following Groth) the brachypinaccid ( $i-r^{\prime}$ ) of the Orthorhombic. Similarly ( $h 0 l$ ) belongs to the oriho-

[^55]domes of the Monoclinic, and the macrodomes of the Orthorhombic system; also (0kT) belongs to the clinodomes of the former, and the brachydomes of the latter. See also p. 457 .

Spherical Projection.-If the centre of a crystal, that is, the point of intersection of the, three axes, be taken as the centre of a sphere, and normals be drawn from it to the successive planes of the crystals, the points, where they meet the surface of the sphere, will be the polss of the respective planes. For exan.ple, in f. 750 the common centre of the crystal and sphere is at 0 , the normal to the plane $b$ meets the surface of the sphere at $B$, of $b^{\prime}$ at $B^{\prime}$, of $d$ and $c$ at D and E respectively, and so on. These poles evidently determine the position of the plane in each case.

It is obvious that the pole of the plane $b^{\prime}$ ( $0 \overline{1} 0$ ) opposite $b(010$ ), will be at the opposite extremity of the diameter of the sphere, and so in general, $(120)$ and ( 120 ), etc. It is seen also that all the poles, or normal points, of planes in the same zone, that is, planes whose intersection-lines are parallel, are in the same great circle, for instance the planes $b(010), d(110), a(100), c(1 \overline{1} 0)$, and so on.

It is customary* in the use of the sphere so regard it as projected upon a horizontal
 plane, usually that normal to the prismatic zone, so that, as in f . 759 , the prismatic planes lie in the circumference of the circle, and the other planes within it. The eye being supposed to be situated at the opposite extremity of the diameter of the sphere normal to this plane, the great circles then appear either as arcs of circles, or as straight lines, i.e., diameters.

It will be further obvious from f. 756 that the arc BD , berween the poles of $b$ and $d$, mea sures an angle at the centre (BOD), which is the supplement of the actual interior angle bnd between the two planes. This fact, that the arc of a great circle intercepted between the poles of two planes always gives the supplement of the actual angle between the planes themselves, is most important, and does much to facilitate the ease of calculation. In consequence of this, it is customary with many crystallographers to give for the angle between two planes, not the interfacial angle, but that between their normals.

It is one of the great advantages of this method of projection that it may be employed to show not only the relative positions of the planes, but also those of the optic axes, and the axes of elasticity.

Relation between the indices of a plane and the angle made by it with the axes - When the assumed axes are at right angles to each other they coincide with the normals to the pinacoid planes ( $001,010,100$ ). and consequently meet the spherical surface at their poles. When the axial angles are not $90^{\circ}$, this is no longer true. In ail cases, however, the following relation holds good between the cosines of the angles made by a plane with the axes:

$$
\frac{\partial p}{O H}=\cos \mathrm{PX} \quad \frac{\partial p}{O K}=\cos \mathrm{PY} \quad \frac{\partial p}{O L}=\cos \mathrm{PZ} .
$$

But from the equation (1) before given, by the introduction of the values of $\mathrm{OH}, \mathrm{OK}, \mathrm{OL}$, we obtain:

$$
\begin{equation*}
\frac{a}{h} \cos \mathrm{PX}=\frac{b}{k} \cos \mathrm{PY}=\frac{c}{l} \cos \mathrm{PZ} \tag{2}
\end{equation*}
$$



This equation is fundamental. and many of the relations given beyond are dedinced from it. It will be seen that in the case of the orthometric systems the angles PX. PY, PZ are the supploment-angles between any plane ( $h k l$ ) and the pinacoids ( 001 ), ( 010 ), (100).

Relations betioeer. planes in the same zone.-By the use of the equation (2), it may be shows
that if two planes ( $(h k d)$ and ( $p q r$ ) lie in the same zone, that the following equation must hold good :

$$
\mathrm{u} a \cos \mathrm{XQ}+\mathrm{v} b \cos \mathrm{YQ}+w c \cos \mathrm{ZQ}=0 .
$$

where

$$
\mathrm{a}=k r-l q, \quad \mathrm{v}=l p-h r, \quad \mathrm{w}=h q-k p .
$$

The letters $\mathbf{u}, \mathrm{v}, \mathrm{w}$ are called the symbol of the zone or great circle PR. Every plane $\mathbf{R}(x y z)$ of this zone must satisfy the equation:

$$
\begin{equation*}
\mathrm{u} x+\mathrm{v} y+\mathrm{w} \hat{2}=0 \tag{3}
\end{equation*}
$$

If now (uvw) be the symbol of one zone, and (efg) of another intersecting it, then the point of intersection will be the pole of a plane lying in both zones, whose indices ( $h k l$ ) must satisfy two equations similar to (3). These indices are equal to:

$$
h=\mathrm{gv}-\mathrm{fw} \quad k=\mathrm{ew}-\mathrm{gu} \quad l=\mathrm{fu}-\mathrm{ev} .
$$

The application of this principle is extremely simple, and its importance cannot be overextimated. Some examples are added here, showing the method of use.

Exramples of the methods of calculation by zones.-(1) For the zone of planes between (100) and ( 001 ), the zone indices are $u=0, v=-1, w=0$. They are obtained by multiplication in the manner indicated in the following scheme:

In general


Consequently every plane ( $h k l$ ) in the zone named must answer the condition: $\mathrm{u} h+\mathrm{v} \kappa$ $+\cdot \mathrm{w} l=0$, that is, in this case $k=0$. The general symbol is consequently ( $h 06$ ). Compare \&. 759 .
(2) For the zone (001), (010), in a similar manner:

$\mathbf{u}=\overline{1}, \boldsymbol{v}=0, \mathrm{w}=0$, and the equation of condition becomes $h=0$, and the general sym. bol is (0kl). Compare f. 759.
(3) For the prismatic zone between (100) and (010), the general symbol will be found to be ( $h k 0$ ). Compare f. 759.

(4) For the pyramidal zone between the basal plane (001) and the unit prism (110), we have the scheme:


Hence $u=\overline{1}, v=1, w=0$, and the equation of condition becomes $h=k$, and hence the general symbol is $h l l$ for the unit pyramids.

For a plane lying at once in two zones, for instance the plane lettered $2-2$ in f . 758 , lying in the zone $1,2-2,1-\check{\imath}$, and in the zone $i-\tau, 3-\check{\imath}, 2-2,1,1-\bar{\imath}$. The indices, uvw, for the first zone 1-乞 (011), $I$ (110), are, obtained as above, $u=\overline{1}, v=1, w=\overline{1}$. Again, for the zone between $i-\bar{\imath}$ ( 010 ), 1- $\bar{\imath}(101)$, the zone indices, cfg, are, $\mathrm{e}=\mathrm{l}, \mathrm{f}=0, \mathrm{~g}=1$. The indices ( $h k l$ ), for the plane (2-2) lying in both these zones, and hence answering to two equations of condition, are obtained by multiplication in a scheme exactly like that already given, viz.:
In general

$$
h=\mathrm{gv}-\mathrm{fw} ; k=\mathrm{ew}-\mathrm{gu} ; l=\mathrm{fu}-\mathrm{ev} .
$$

$\overline{1}$
$h=1 ; k=2 ; l=1$.

The plane has consequently the symbol (121).

For the zone of planes, lettered on the figure (f. 758) $i-\check{\imath}, 3-\breve{3}, 2-2 \breve{2}$, etc., the indices, as already shown, are $\mathrm{e}=1, \mathrm{f}=0, \mathrm{~g}=1$, and consequently the equation of condition reduces to $\hbar=l$, and the general symbol is $h k h$. This zone is shown on the spherical projection, f. 759, and includes the planes $010(i-\check{\imath}), 131(3-3 /), 121$ (2-2̆, 111 (1), 101 (1-ī), and so on.

A second examp e of the above method is afforded by the plane lettered $2-\overline{2}$ in f. 758. It lies in the zone $i-\bar{\imath}(100)$ to $1-\check{\imath}$ (011), whose indices, uvw, obtained as before, are, $u=0, v=\overline{1}, w=1$. It is also in the zone between $I(110)$ and $1-\bar{\imath}(101)$, whose indices, efg. are, $\mathrm{e}=1, \mathrm{f}=\overline{\mathrm{1}}, \mathrm{g}=\overline{\mathrm{1}}$. Its own symbol ( $h k l$ ) is deduced as above:


Tha symbol is consequently (211). The
 position of this plane is shown on the spherical projection, f. 759, as also that of the zone first mentioned above, whese indices were $\mathrm{u}=0, \mathrm{v}=1, \mathrm{w}=1$, and for which the equation (3) consequently reduces to $k=l$; the general symbol is then $(h k k)$, the planes $100(i-\bar{\imath}), 211(2-\overline{2}), 111(1), 011(1-\bar{i})$, etc., belong in this zone.

The example employed here serves to show the extensive application of this principle of zones. Supposing that in this crystal, f. 758, $I(110)$, and $1 \cdot \check{\imath}(011)$ have been assumed as fundamental planes in their respective zones, the symbols of all the others may be obtained in this way, without the necessity of a single measurement ; the reflecting goniometer would indicate the presence of the few necessary zones not shown by the parallel intersections.

Methods of Calculation.-In consequence of the wide application of this method of determining the symbols of a plane by the zones in which it lies, actual trigonometrical calculations are not very frequently required. The methods employed are always those of spherical trigonometry, and in most cases no formulas are needed, the problems arising requiring nothing but the solution of the triangles, mostly right-angled, seen on the spherical projection. It is to be remembered that an are of a great circle, between two poles, shown in the projection, is always the supplement of the actual interfacial angle between the planes themselves.

Some of the more commonly used formulas for the solution of spherical triangles which have been already given on p. 62, are, for the sake of convenience, repeated here.

In right-angled spherical triangles $\mathrm{C}=90^{\circ}, h=$ the hypothenuse.

$$
\begin{array}{ll}
\operatorname{Sin} \mathbf{A}=\frac{\sin a}{\sin h} & \sin \mathbf{B}=\frac{\sin b}{\sin h} \\
\operatorname{Cos} \mathbf{A}=\frac{\tan b}{\tan h} & \cos \mathrm{~B}=\frac{\tan a}{\tan h} \\
\operatorname{Tan} \dot{A}=\frac{\tan a}{\sin b} & \tan \mathrm{~B}=\frac{\tan b}{\sin a} \\
\operatorname{Sin} \mathbf{A}=\frac{\cos \mathrm{B}}{\cos b} & \sin \mathbf{B}=\frac{\cos \mathbf{A}}{\cos \frac{1}{a}} \\
\begin{array}{ll}
\cos h=\cos a \cos b \\
\cos h & =\cot \mathrm{A} \cot \mathrm{~B}
\end{array}
\end{array}
$$

In cblique angled spherical triangles:
(1) $\operatorname{Sin} \mathrm{A}: \sin \mathrm{B}=\sin a: \sin b$;
(2) $\operatorname{Cos} a=\cos b \cos c+\sin b \sin c \cos A$;
(3) $\operatorname{Cot} b \sin c=\cos c \cos \mathbf{A}+\sin \mathbf{A} \cot \mathbf{B}$;
(4) $\operatorname{Cos} A=-\cos B \cos C+\sin B \sin C \cos \omega$.

In calculation it is often more convenient to use, instead of the latter formulas, those especially arranged for logarithms, which will be found in any of the many kooks devoted to mathematical formulas.

In addition to the mere solution of triangles on the spherical projection, it is also necessary to connect by equations the actually measured angles with the lengths and inclinations of axes of the crystals themselves. These equations are given in connection with the different systems.

The folowing relation between the planes in the same zone is also of very wide application :

Let $P, Q, S, R$ be the poles of four planes in a zone (f. 760), having the following indices, viz. : $\mathbf{P}=(l k l), \mathbf{Q}=(p q r), \mathbf{R}=(u v w), \mathbf{S}=(x y z)$. The folowing relation may
760


$$
\begin{equation*}
\frac{\cot P s-\cot P R}{\cot P Q-\cot P R}=\frac{(P . Q)}{(Q . R\}} \cdot \frac{(S . R)}{(P . S)} \tag{4}
\end{equation*}
$$

$$
\begin{align*}
& \frac{(\mathrm{P} . \mathrm{Q})}{(\mathrm{Q} . \mathrm{R})}=\frac{k r-l q}{q v-r v}=\frac{l p-k r}{r u-p w}=\frac{h q-k p}{p v-q u} \\
& \frac{(\mathrm{~S} . \mathrm{R})}{(\mathrm{P} . \mathrm{S})}=\frac{v y-z v}{k z-l y}=\frac{z u-x w}{l x-h z}=\frac{x v-y u}{h y-k x} \tag{5}
\end{align*}
$$

By means of the above equation it is possible to deduce the indices or angle of a fourth plane, when those of the threc others are given. In the application of this principle it is essential that the planes should be taken in the proper order, as shown above; to accomplish this it is often necessary to use the indices and corresponding angles, not of (hlkl), but its opposite plane ( $\bar{h} \bar{k} \bar{l}$ ), etc.

In the orthometric systems this relation admits of being much simplified.
If one of the above four planes coincides with a pinacoid plane (100), (010), or (001), and another with a plane in a zone with a second pinacoid $90^{\circ}$ from the first, then the following relations hold good for two planes $\mathrm{P}(\hbar k l)$, and $\mathrm{Q}(p q r)$ in this zone:

$$
\begin{aligned}
& \frac{h}{p} \cdot \frac{\tan \mathrm{PA}}{\tan \mathrm{QA}}=\frac{k}{q}=\frac{l}{r} \\
& \frac{h}{p}=\frac{k}{q} \cdot \frac{\tan \mathrm{~PB}}{\tan \mathrm{QB}}=\frac{l}{r} \\
& \frac{h}{p}=\frac{k}{q}=\frac{l}{r} \cdot \frac{\tan \mathrm{PC}}{\tan \mathrm{QC}}
\end{aligned}
$$

As a further simplification of the above $\epsilon$ quation for the case of a prismatic plane ( $/ \hbar \% 0$ ), or a dome ( $h 0 l$ ) or ( $0 k l$ ), between two pinacoid planes $90^{\circ}$ from another, we have :

$$
\frac{h}{k}=\frac{\tan (100)(110)}{\tan (100)(h k 0)} ; \quad \frac{h}{l}=\frac{\tan (001)(k 0 l)}{\tan (001)(101)} ; \quad \frac{k}{l}=\frac{\tan (001)(0 k l)}{\tan (001)(011)} .
$$

These equations are the ones ordinarily employed to determine the symbol of any prismatic plane or dome. It will be seen at once that all the above relations for rectangular zones are essentially identical with those given on p. 59, though here expressed in a clearer and more concise form.

## Systems of Crystailization.

All crystals are divided into six classes, according to the degree of symmetry which characterizes them. This symmetry. as well as the relations of the different planes of a crystal, is shown in the lengths and position of the axes which are taken for each. With reference to their axial relations crystals are divided into the following six systems:
I. Isometric System.-Three equal axes $(a, a, a)$ at right angles to one another.
II. Tetragonal System.--Two equal lateral axes ( $a, a$ ), and a third vertical axis (í) of us equal length; all at right angles.
III. Hexagonal System. - Three equal lateral axes ( $a, a, a$ ) crossing at angles of $60^{\circ}$, and a fourth vertical axis ( $\dot{c}$ ) of unequal length, perpendicular to the plane of the others.
IV. Orthorhombic System.-Three unequal axes ( $(\bar{c}, \bar{b}, \check{a})$ at right angles to each other.
V. Monoclinic System-Three unequal axes ( $\dot{c}, b, d)$; the angle between $\dot{c}$ and $b$, and between $b$ and $\grave{a}=90^{\circ}$, but the angle between $\dot{c}$ and $\dot{a}$ greater and less than $90^{\circ}$.
VI. Triclinic System.-Three unequal axes $(\dot{c}, \bar{b}, \breve{u})$; the axial angles all obliqua

## I. Isometric System.

The symbol [ $h k l]$ embraces all the forms possible under each system in the most general case. Since in the Isometric System all the axes are of equal value, it obviously follows from the symmetry of the system that each one of the indices may be exchanged for each of the others, so that the total number of planes possible will be given by all the arraugement of the indices $\pm h, \pm k, \pm l$, or as follows:

| likl | luk | kihb | kllh | luk | $1, \ldots h$ |
| :---: | :---: | :---: | :---: | :---: | :---: |
| $h \overline{k l}$ | lilk | $k h l$ | kilh | $l \bar{h} k$ | lkik |
| $\hbar k l$ | hlk | kihl | Elh | Thk | lkh |
| hkb | hik | Ehh | kilh | lhk | likh |
| hkl | $h l \bar{K}$ | khl | $k l h$ | lhk | $l k h$ |
| k $k$ kl | $h 7 / \bar{L}$ | $h \overline{h l}$ | $k i \bar{h}$ | lh\% | lk $\quad$ h |
| $\pi k l$ | $h l / k$ | i.hl | $\bar{k} \iota \bar{h}$ | lhh | lk $/ 2$ |
| hkl | hilk | $\bar{k} \%$ | ki̇h | $i \hbar \bar{k}$ | lk |

## A. Holohedral Forms.

There are seven cases possible among the holohedral forms of this system, according to the value.s of $h, k, l$. These are shown in the list below, to which are added the symbols, after Naumann, given on p. 14, though, as already explained, written in the inverse order. In the most general case $[h k l]^{*}$ the form includes forty eight similar planes, aud in the most special case [100], there are included six similar planes.

## Miller.

1. $[h k l] ; h>k>l$.
2. $[h k k] ; h>k$.
3. $[h h k] ; h>k$.
4. $[11!] ; h=k=l=1$.
5. $[h k 0] ; l=0$.
6. $[110] ; h=k=1 ; l=0$.
7. $[100 \mathrm{j} ; h=1, k=l=0$.

## Naumann.

| $a: n a: m a$ | $[m-n]$. |
| :--- | :--- |
| $a: m a: m a$ | $[m-m]$. |
| $a: a: m a$ | $[m]$. |
| $a: a: a$ | $[1]$. |
| $a: n a: \infty a$ | $[i-n]$. |
| $a: a: \infty a$ | $[i$. |
| $a: \infty a: \infty a$ | $[H]$. |

The seven distinct forms corresponding to these symbols are as follows, taken in the same order as on f $p$ 14-20, where the forms are described:

Cube (f. 7bil). -Symbol [100], including the six planes (100), (010), ( $\overline{1} 00),(0 \overline{1} 0),(001)$. $(001)$. See also the spherical projection (f. 766).


Octahedron (f. 762).-Symbol [111], including the eight planes taken in order shown in f. $762,(111),(\overline{1} 11),(\overline{1} \overline{1} 1),(1 \overline{1} 1),(11 \overline{1}),(\overline{1} 11),(\overline{1} 1),(1 \overline{1} 1)$.

[^56]Wodecahedron (f. 763).-Symbol [110], including the twelve planes, (110), ( $\overline{1} 10$ ), (110), (110), (101), (011), ( $\overline{1} 01$ ), ( $0 \overline{1} 11),(10 \overline{1}), ~(01 \overline{1}), ~(\overline{1} 0 \overline{1}), ~(0 \overline{1} \overline{1})$.

The relations between these three forms are given in full on pp. 15, 16, and need not be repeated. It is to be noticed that the distance between two contiguous poles of [100] and [110] is $45^{\circ}$ (see f .766 ) ; between those of [100] and [111] it is $54^{\circ} 44^{\prime}$, and between (110) and (111) it is $35^{\circ} 16^{\prime}$. Moreover, the angle between (111) and (111) is $70^{\circ} 32^{\prime}$, and between (111) and (111), $109^{\circ} 28^{\prime}$.


Tetragonal trisoctahedron (f. 767, 768).-Symbol [ $h k k]$, with $h>k$, comprising twenty-fous similar planes.

Trigonal trisoctahedron (f. '769).-Symbol [hhk], with $h>k$, also embracing twenty-four like planes.


Tetrahexahedron (f. 770. 771).-Symbol [hk0] incluling twenty-four like planes. As seen on the spherical projection (f. 766), the planes of the form [ $h k 0$ ] lie in a zone with the dodecahedral planes, between two pinacoid planes.

Hexoctahedron (f. 772), [hkl]. -This is the most general form in the system, including the forty-eight planes enumerated on p. 447. Their position ( $h=3, l=2, l=1$ ) is shown on the spherical projection (f. 766).

## B. Hemihedral Forms.

There are two kinds of hemihedral forms observen, as shown on p. 20: (1) the hemihola liedral, where half the quadrants have the whole number of planes; and (2) the holohemihedrai where all the quadrants have half the full number of planes. The first kind produces inclined hemihedrons, indicated by the symbol $\left.\kappa_{i} \hbar h k\right]$, and the second kind produces paralle nemihe. drons, indicated by the symbol $\pi[\hbar k h]$. The resulting forms in the several cases are as follows $\cdot$

Inclined Heminedrism.-Tetrahedron ( $\pm 1$ ). Symbol $\kappa[111]$. The plus tetrahedron (f. 773 ) includes the four planes (111), ( $\overline{1} 11$ ), ( $11 \overline{1}$ ), (1111). The minus tetrahedon (f. 774) includes the planes (111), (111), (111), ( $\overline{1} \overline{1} \overline{1})$.


Hemi-trisoctakedrons.-The symbol $\kappa[h k k]$ denotes the solid shown in f. 775, and $\kappa[h h k!$ the solid shown in f. 776. They are the hemihedral forms of the tetragonal and trigonal trisoctahedrons respectively.

Hemi-heroctahedron. - The same kind of hemiledrism applied to the hexoctahedron produces the form shown in f. 777, having the general symbol $\kappa[h k l]$.

Inclined hemihedrism as applied to the three other solids of this system produces forms in no way different, in outward appearance, from the holohedral forms.

Parallel Hemifedrism produces distinct, independent, forms only in the case of the tetrahexahedron and the hexoctahedron. The symbol of the former is $\pi[h k 0]$, and of the latter, $\pi[h k l]$; they are shown in f. 778-782.


Tetartohedral forms of several kinds are possible in this system, but they are of small practical interest.

## Mathematical lelations of the Isometric System.

(1) The distance of the pole of any plane $\mathrm{P}(\mathrm{lkl})$ from the cubic (or pinacoid) planes is given by the following equations. 'These are derived from equation (2), p. 443. Here PX(=PA) is the distance between ( $h k l$ ) and $(100) ; \mathrm{PY}(=\mathrm{PB})$ is the distance between ( $h k l$ ) and ( 010 ); a.d $\mathrm{PZ}(=\mathrm{PC})$ that between ( $h k l$ ) and ( 001 ).

The following equations admit of much simplification in spécial cases, for ( $h k 0$ ), ( $h k k$ ), eto.

$$
\cos ^{2} \mathrm{PA}=\frac{h^{2}}{h^{2}+k^{2}+l^{2}}, \quad \cos ^{2} \mathrm{~PB}=\frac{k^{2}}{h^{2}+k^{2}+l^{2}}, \quad \cos ^{2} \mathrm{PC}=\frac{l^{2}}{h^{2}+k^{2}+l^{2}} .
$$

(2) The distance between the poles of any two planes ( $h k l$ ) and ( $p q r$ ) is given by the following equation, which in special cases may also be more or less simplified:

$$
\cos \mathrm{PQ}=\sqrt{\left(h^{2}+k^{2}+l^{2}\right)\left(p^{2}+q^{2}+r^{2}\right)}
$$

(3) Calculation of the values of $h, k, l$, for the several forms.-(a) Tetragonal trisoctake. dron (f. 767). B and $C$ are the supplement angles of the edges as lettered in the figure.

$$
\cos \mathrm{B}=\frac{h^{2}}{h^{2}+2 k^{2}}, \quad \cos \mathrm{C}=\frac{2 \hbar k+k^{2}}{k^{2}+2 k^{2}}
$$

For the hemihedral form (f. 775), $\cos \mathrm{B}=\frac{h^{2}-2 k^{3}}{h^{2}+2 k^{2}}$.
(b) Trigonal trisoctahedron.-The angles A and C are, as before, the supplemencs of the interfacial angles of the edges lettered as in f. 769.

$$
\cos \mathrm{A}=\frac{k^{2}+2 h k}{2 h^{2}+k^{2}} \cdot \quad \cdot \cos \mathrm{~B}=\frac{2 h^{2}-k^{2}}{2 h^{2}+k^{2}} .
$$

For the hemihedral form (f. 776), $\cos \mathrm{B}=\frac{h^{2}-2 h k}{2 h^{2}+k^{2}}$.
Tetrahexahedion (f. 770),

$$
\cos \mathrm{A}=\frac{\hbar^{2}}{h^{2}+k^{2}} ; \quad \cos \mathrm{C}=\frac{2 h k}{h^{2}+k^{2}}
$$

For the hemihedral form (f. 778), $\cos \mathrm{A}^{\prime \prime}=\frac{\hbar^{2}-k^{2}}{\hbar^{2}+k^{2}} \cdot \cos \mathrm{C}^{\prime \prime}=\frac{h k}{\hbar^{2}+k^{2}}$.
Hexoctahedron (f. 772).

$$
\cos \mathrm{A}=\frac{\hbar^{2}+2 k l}{\hbar^{2}+k^{2}+l^{2}} ; \cos \mathrm{B}=\frac{\hbar^{2}+k^{2}-l^{2}}{\hbar^{2}+k^{2}+l^{2}} ; \quad \cos \mathrm{C}=\frac{2 h k+l^{9}}{\hbar^{2}+k^{2}+l^{2}} .
$$

For the hemihedral form $\kappa[h l k l]($ f. 777$), \cos B^{\prime}=\frac{h^{2}-2 k l}{k^{2}+k^{2}+l^{2}}$.
Foz $\pi[\hbar k l], \cos \mathrm{A}^{\prime}=\frac{\hbar^{2}-k^{2}+l^{2}}{k^{2}+k^{2}+l^{2}} ; \cos \mathrm{C}^{\prime}=\frac{k l+l h+l k}{h^{2}+k^{2}+l^{2}}$.
For planes lying in the same zone the methods of calculation given on p. 444 and p. 446 are made use of. In many cases, however, the simplest method of solution of a given problem is by means of the spherical triangles on the projection (f. 766).

## II. Tetragonal System.

In the Tetragonal System, since the vertical axis $\dot{c}$ has a different length from the two equal lateral axes, the index $l$, referring to it, isnever exchangeable for the other indices, $h$ and $k$. The general form [ $h k l]$ consequently embraces all the planes which have as their symbols the different arrangements of $\pm h, \pm k, \pm l$, in which $l$ always holds the last place. We thus obtain:

| hkl | hi\% | hFl | Fikl | $k h \bar{l}$ | Kht | Kinb | k,hl |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 1 kl | hkil | hkl | $\pi k l$ | khl | ThJ | khl |  |

## A. Holohedral Forms.

According to the values of $k, k$, and $l$ in this general form ( $k=0, k=h$, etc.), different cases may arise. By this means we obtain a list of all the possible distinct holohedral form in tluis system. They are analogous to those of the Isometric System.

## Miller.

1. $[h k l] ; \pi>k$.
2. $[h h l] ; h=k$.
3. $[h 0 l] ; k$ or $l=0$.
4. $[l k 0] ; h>k, l=0$.
5. $[110] ; h=k=1, l=0$.
6. $[100] ; k=0, l=0$.
7. [001] ; $h=k=0$.

## Naumann.

| $a: n a: m c$ | $[m-n]$. |
| :--- | :--- |
| $a: a: m c$ | $[m]$. |
| $a: \infty a: m c$ | $[m-i]$. |
| $a: n a: \infty c$ | $[i-n]$. |
| $a: a: \infty c$ | $[[]$. |
| $a: \infty a: \infty c$ | $[i-i]$. |
| $\infty a: \infty a: c$ | $[0]$. |

The forms answering to these general symbols (compare f. 790) are as follows:
Basal planes.-Symbol [001], including the planes (001) and (001).
Prisms.-(a) Diametral prism, or that of the second series (f. 783). Symbol [100], in cluding the four planes (100), (010), ( $\overline{1} 00),(0 \overline{1} 0)$.
(b) Unit prism, or prism of the first series (f. 784).-Symbol [110], embracing the fous planes (110). ( $\overline{1} 10$ ), ( $\overline{1} 10$ ), ( $1 \overline{1} 0$ ). The relation of these two prisms is shown on p. 26.
(c) Octagonal prism (f. 785).-Symbol [ $7 k 0]$, including the eight plaues $(\hbar k 0),(k h 0)$, ( $k / 0$ ), ( $\bar{k} k 0$ ), ( $\bar{h} \bar{k} 0)$, ( $\bar{k} \bar{h} 0),(k \bar{h} 0),(h \bar{k} 0)$.

Octahedrons or Pyrumids. - There are two series of octahedral planes, corresponding to the two square prisms. (a) Octahedrons of the second, or diametrai series. Symbol [h0h], including eight similar planes. The form [101] is shown in f. 786.
(b) Octahedrons of the first, or unit series.-Symbol [ $7 k l]$, embracing eight similar planes. The form [111] is shown in f. 787.


Octagonal Pyramids.-The general symbol [ $h k l$ ] embraces, as already shown, sixteen like planes, whirh together form the octagonal pyramid shown in f. 788.


The relations of the various tetragonal forms will be understood by reference to f. 790, showing the projection for the crystal represented in f. 789.

## B. Hemihedral Forms.


$\pi[111]$

## Mathematical Relations of the Tetragonal System.

(1) The distances of the pole of any plane $\mathbf{P}(h k l)$ from the pinacoid planes $100(=\mathrm{PA}), 010$ $=\mathrm{PB}), 001(=\mathrm{PC})$ are given by the following equations:

$$
\cos ^{2} \mathrm{PA}=\frac{h^{2} c^{2}}{h^{2} c^{2}+k^{2} c^{2}+l^{2} a^{2}} ; \cos ^{2} \mathrm{~PB}=\frac{k^{2} c^{2}}{h^{2} c^{2}+k^{2} c^{2}+l^{2} a^{2}} ; \cos ^{2} \mathrm{PC}=\frac{l^{2} a^{2}}{h^{2} c^{2}+k^{2} c^{2}+l^{2} a^{2}}
$$

These may also be expressed in the form :

$$
\tan ^{2} \mathrm{PA}=\frac{k^{2} c^{2}+l^{2} a^{2}}{k^{2} c^{2}} ; \tan ^{2} \mathrm{~PB}=\frac{\hbar^{2} c^{2}+l^{2} a^{2}}{k^{2} c^{2}} ; \tan ^{2} \mathrm{PC}=\frac{k^{2} c^{2}+k^{2} c^{2}}{l^{2} a^{2}}
$$

(2) For the distance between the poles of any two planes $(h k l),(p q r)$, we have in general :

$$
\cos \mathrm{PQ}=\frac{l p c^{2}+k q c^{2}+l r a^{2}}{\sqrt{\left[\left(h^{2}+k^{2}\right) c^{2}+l^{2} a^{2}\right]\left[\left(p^{2}+q^{2}\right) c^{2}+r^{2} a^{2}\right]}}
$$

The above equations take a simpler form for special cases often occurring.
(3) Planes in the same zone.-For the general case of planes ( $h k l$ ) and ( $p q r$ ) the re lation given in equation 4 (p. 446) is made use of. In the special cases, practically of the most importance, where the planes lie in a zone with a pinacoid plane, the simplified formulas are employed.

For the octagonal prism this relation becomes:

$$
\tan (100)(h k 0)=\cot (010)(h k 0)=\frac{k}{h} .
$$

Determination of the axis $\dot{c}$.-This follows from equation (1), p. 446, which, for this case becomes:

$$
\frac{1}{h} \cos \mathrm{PA}=\frac{\dot{c}}{l} \cos \mathrm{PC},(a=1)
$$

For an octahedron ( $h 0 l$ ) in the diametral series, we have:

$$
\tan (h 0 l)(001)=\frac{i \hbar}{l}
$$

For the unit octahedron (111), we have:

$$
\tan (111)(001) \cdot \cos 45^{\circ}=\delta
$$

## III. Hexagonal System.

The Hexagonal System and its hemihedral, or rhombohedral, division are both included by Miller in his Rhombohedral System (see p. 462). All hexagonal and rhombohedral forms are referred by him to three equal axes, oblique to one another, and normal to the faces of the unit rhombohedron. This method has the great disadvantage of failing to exhibit the hexagonal symmetry existing in the holohedral forms, since in this way the similar planes of a hexagorial pyramid receive two different sets of symbnls, having no apparent connection with each other. It, moreover, hides the relation between this system and the tetragonal system. which, optically, are identical, since they possess alike one axis of optical symmetry.

The latter difficulty was avoided by Schrauf, who introduced the Orthohexagonal SysTEM. In this the optical axis was made the crystallographical vertical axis, and otherwise two lateral axes, at rightangles to each other, were assumed, $a$ and $a \backslash \overline{3}$. This method, however, does not overcome the other objection named above.

In the method of Weiss and Naumann a vertical axis. coinciding with the optical axis, was ndopted, and three lateral axes in a plane at right angles to it, they intersecting at angles of $60^{\circ}$, corresponding to the planes of symmetry in the holohedral forms (see p. 462). In this way nnly can the symmetry of the hexagonal forms be clearly brought out, and at the same
time the relation between the hexagonal and tetragonal systems exhibited. Recently Groth (T'sch. Min. Mitth., 1874, 223, and Phys. Kryst., 1876, p. 252) has shown that the complete symbols of Weiss and Naumann could be translated into a reciprocal, integral form after the manner of Miller. The symbols then obtained, as was aiso shown, admit of a like convenient use in calculation. Essentially the same method was proposed in 1866 by Bravais, and his suggestion is followed here; the more important equations, expressing the relations between the poles of the planes, their indices, and the axes of the crystal are also added. They are given somewhat in detail, since they are not included in any of the works ou Miller's System before referred to.

All hexagonal forms are referred to a vertical axis, $\dot{c}$, and three equal lateral axes in a plane at right angles to it, intersecting at angles of $60^{\circ}$ and $120^{\circ}$ (f. 792). The general symbol for a plane in this system is ( $k k l i$ ), where it is always true that the algebraic sum of $h, k, l$ is zero, that is, $h+k+l=0$. The indices here are the reciprocals of those of Naumann, except that the index $l$ has the opposite sign, and the order of two of the indices is inverted. According to him the general symbol of any plane is $m-n(=m \mathrm{P} n)$, or, in full, $\frac{n}{n-1} a: a: n a: m c$. Thus the plane $3-\frac{3}{2}\left(3 \mathrm{P}_{\frac{3}{2}}^{2}\right)$ has the full symbol, $3 a: a: \frac{3}{2} a: 3 c$, or to correspond with the other symbols it must be written, $3 a: \frac{3}{2} a: a: 3 c$. The reciprocals of the latter indices are $\frac{1}{8}: \frac{7}{\frac{2}{2}}: 1: \frac{1}{\frac{1}{2}}$, or, reduced to integers (and changing the sign of l) (1231), which is the symbol according to the plan here followed. Similarly the plane ( $2, \overline{4} 3$ ) gives, on taking the reciprocals, $\frac{1}{2} a: \frac{1}{2} a: \frac{1}{4} a: \frac{1}{3} c$, which is equivalent to $2 a: 2 a$
 : $a: \frac{4}{3} c$, or in Naumann's abbreviated form ${ }_{3}^{4}-2\left(={ }_{3}^{4} \mathrm{P} 2\right)$.

It is the great advantage of this method that it makes it possible to change the almost uni. versally adopted symbols of Weiss and Naumann into a form which allow of all the readiness of calculation and the application to the spherical projection which are the characteristics of Miller's System.

In calculations, both by zone equations and other methods, ouly two of the indices $h, k$, or $l$ of the form ( $h k l i$ ) need be employed, with the remaining index $i$ (referring to the vertical axis). This is obviously true, since the three indices named are counected by the equation $h+k+l$ $=0$. Disregarding, then, in calculation the third index $l$, as shown beyond, the planes are referred to two equal lateral axes, intersecting at an angle of $120^{\circ}$, and a third vertical axis $c$.

The symbol [ $h k \bar{i}$ ] in its more general form embraces twenty-four planes, as is evident from an inspection of the spherical projection, f. 793. Here $h, k, l$ are of equal value and mutually exchangeable, with the condition, however, that their algebraic sum shall always equal
 zero. Of the twenty-four planes of the dihexagonal pyramid, the following are those of the upper quadrants mentioned in order from left to right around the circle (f. 793). Those below have the same symbols, except that the index $i$ in each case is minus:
$(h k i i)$
$(h \bar{k} l i)$
$\left(\begin{array}{l}(h h \bar{k} i) \\ (h \bar{l} k i)\end{array}\right.$
( ${ }^{(k i l h i)}$
( $\overline{(i k h i})$
${ }^{(T i h k i}$
( $\bar{k} h l i)$
(khli)

In this general form [ $h \kappa / \bar{i}]$ the following special cases are possible, each one giving rise to an independent form or group of forms, as seen below :

## Bratais-Miller.



| 1 | [hkli] |  |
| :---: | :---: | :---: |
| 2 | $\{[h \hbar 2 \overline{2} 2 i]$; | $k=h . \therefore l=2 h$ |
| 2 | \{ [1122] ; | $h=k=1 \therefore l=2, i=2$ |
| 3. | \{ $00 h \bar{\sim} i] ;$ | $k=0 . \therefore l=h$ |
| 3. | \{ [0111]; | $h=1, k=0 \therefore l=1$ |
| 4. | [ $k \mathrm{k} 20]$; | $i=0$ |
| 5. | [1120]; | $i=0, h=k=1 . \therefore l=2$ |
| 6. | [0110]; | $i=0, k=0, h=1 . \therefore l=1$ |
| 7 | [0001]; | $h=k=l=0$. |

## Naumann.*

| $\frac{n}{n-1}: n a: a: m c$ | [ $m$ - $\boldsymbol{n}$ ] |
| :---: | :---: |
| \{ $2 a: 2 a: a: m c$ | -2] |
| $\{2 a: 2 a: a: c$ | [1-2] |
| $\{\infty a: a: a: m c$ | [ $m$ ] |
| $\{\infty a: a: a: c$ | [1] |
| $n{ }^{n} a: n a: a: \infty c$ |  |
| $\overline{n-1} a: n a: a: \infty c$ | [i-n] |
| $2 a: 2 a \quad a: \infty c$ | [i-2] |
| $\infty a: a: a: \infty<$ | [l] |
| $\infty a: \infty a: \infty a: c$ | [0] |

## A. Holohedral Forms.

The forms to which these symbols belong have been already mentioned on pp. 32-34. They may be briefly recapitulated here. They are taken in the reverse order from that given in the table.
Basal plrnes. - Symbol (0001) and (0001̄).
Prisms.- ., a) The unit prism ( $I$ ). General symbol [0110], including (s ${ }^{\circ}$ f. 793. 794) the six planes with the following symbols: (0110), (1100), (1010), (0 $\overline{1} 10),(1 \overline{1} 00),(1010)$.
(b) The diagonal prism ( $i-2$ ). General symbol [11 $\overline{2} 0]$, including ( $f .793,795$ ) the follow. ing six planes: (11 $\overline{2} 0),(\overline{1} 2 \overline{1} 0),(\overline{2} 110),(\overline{1} 20),(1 \overline{2} 10),(2 \overline{1} 10)$.
(c) The dihexagonal prism ( $i-n$ ). General symbol [ $7 k i 0]$, embracing the following twelve planes mentioned in order:

Hexagonal pyramids. or Quartzoids. - (a) The pyramids of the first or unit series. General symbol [ $0 / h i$ i embracing twelve similar planes. All the pyramids of this series lie in a zone between the unit prism [0110] and the base [0001]. A special case of this is when $h=k=i=1$. The planes of this form (f. 796) are shown on the projection, f. 793.

(b) Pyramids of the second, or dingonal series. General symbol [ $h / 22 \bar{h} 2 \lambda$, including twelve planes, analogous to those of the pyramid unit series. All the pyramids of this series lie in a zone between the diagonal prism, whose general symbol is [11 $\overline{2} 0$ ], and the basal plane [001].

Twelve-sided pyramids, or Berylloids (f. 797).-General symbol [hk7i], including the twentyfour planes enumerated on p. 453.

[^57]
## B. Hemihedral Forms.

The most important of the hemihedral forms in this system are as foll sws :

1. Pyramidal hemihedrism.-This comes under the head of holohemihedral forms, which are vertically direct (see pp. 34, 35). It is indicated like the corresponding hemihedrism in the tetragonal system $\pi[k k \hat{i}]$. It is common on apatite.
2. Rhombohedral hemihedrism.-These included here are hemiholohedral, and vertically alternate. They are indicated in general by $\kappa[h k i \bar{l}]$. This class is important, since it embraces the Rhombohedral Division.
(c) Rhombohedrons. Symbol $\kappa[0 h h i]$; the unit, or fundamental rhombohedron ( $+R$, f. 798) has the symbol $\kappa$ [0111], including the six planes: (0111), (1011), (1101), (1011), (1101), (0111). The negative rhombohedron ( $-R, \mathrm{f}$. r 99 ) includes the planes: (1101), (0111), (101̄1), (011̄1), (1011 ), (110101).
(b) Scalenohedrons (f. 800). Symbol $\kappa\left[h k i{ }^{2}\right]$.
3. Gyroidal, or trapezohedral hemihedrism. - The forms here included are holohemihedral, and vertically alternate. They are indicated by $\kappa$ " $[h k l i]$, see $p .39$.

4. Tetratoiedrism.-This may be (1) rhombohedral, indicated by $\kappa \pi[h k l i]$; or (2) trapezohedral (gyroidal), as common on quartz, having the gen. eral symbol $\kappa \kappa "[h k l i]$.

## Mathematical Relations of the Hexagonal System.

In the Hexagonal System, as has been explained, the symbol in general has the form [ $h k \bar{i} \bar{l}]$, where the algebraic sum of $h, k$, and $l$ is zero. This general symbol has four indices, referring respectively to the three equal lateral axes and the vertical axis, as shown in f. 792, thus showing the fundamental hexagonab symmetry of the forms. Since, however, the position of a plane is known by its intersection with three axes aione, two of the three indices $h, k, l$ are all that are needed in calculation, the third, $l$, being a function, as given above, of $h$ and $k$. The mathematical relations of the planes in this system are brought out by referring them to three axes, viz., two equal lateral axes $I I, K,(=a=1)$ oblique ( $120^{\circ}$ and $60^{\circ}$ ) to one another, and a third axis (c) of unequal length perpendicular to their plane.

This applies also to the calculation by zonal equations. The indices $(u, v, w)$ of the zone in which the planes ( $h k l i)^{\prime}$, ( $p q r t$ ) lie, are given by the scheme:

(1) The distances (see f. 793) of the pole of any plane ( $h k l i$ ) from the poles of the plance (1010), (0110), ( 1100 ), and (0001) are given by the following equations:

$$
\begin{aligned}
& \left.\cos \mathrm{PA}=\cos (h k l i)(10 \overline{1} 0)=\sqrt{3 i^{2}+4 \dot{c}^{\dot{c}^{2}}\left(h^{2}+k h\right.}\right) . \\
& \cos \mathrm{PB}=\cos (h k l i)(01 \overline{1} 0)=\sqrt{ } \frac{\dot{c}(h+2 k)}{3 i^{2}+4 \dot{c}^{2}\left(h^{2}+k^{2}+h k\right)} . \\
& \cos \mathrm{PM}=\cos (h k l i)(\overline{1} 100)=\sqrt{\left.\frac{\dot{c}(k-h)}{3 i^{2}+4 \dot{c}^{2}\left(l^{2}+k^{2}+h \bar{c}\right.}\right)} . \\
& \cos \mathrm{PC}=\cos (h k l i)(0001)=\sqrt{\left.\sqrt{3 i^{2}+4 c^{2}\left(h^{2}+. c^{2}+h k\right.}\right)} .
\end{aligned}
$$

(2) The distance ( PQ ) between the poles of any two planes ( $k \pi l i$ ) and ( $p q r t$ ) is giver by the equation:

$$
\cos \mathrm{PQ}=\sqrt{\left[3 i^{2}+4 \dot{c}^{2}\left(h^{2}+k^{2}+h k\right)\right]\left[3 t^{2}+4 \dot{c}^{\circ}\left(p^{2}+q^{2}+p q\right)\right]^{\circ}} .
$$

(3) For special cases the above formula becomes simplified; it serves to give the value of the normal angles for the several forms in the system. They are as follows:
(a) Hexagonal Pyramid [0h有i], f. 796,

$$
\cos X(\text { terminal })=\frac{3 i^{2}+2 h^{2} \dot{c}^{2}}{3 i^{2}+4 h^{2} c^{2}} ; \cos Z(\text { basal })=\frac{47 i^{2} \dot{c}^{2}-3 i^{2}}{3 i^{2}+4 i^{2} \dot{c}^{2}} .
$$

For the hexagonal pyramids of the second series [0h2 $22 i]$ the angles have the same value.
(b) Dihexagonal Pyramid [hkli],

$$
\begin{aligned}
& \cos \mathrm{X} \text { (see f. 797) }=\frac{3 i^{2}+2 \dot{c}^{2}\left(h^{2}+k^{2}+4 h k\right)}{3 i^{2}+4 \dot{c}^{2}\left(h^{2}+k^{2}+h \grave{k}\right)^{\circ}} \\
& \cos \mathrm{Y}(\text { see f. } 797)=\frac{3 i^{2}+2 \dot{c}^{2}\left(2 k^{2}+2 \hbar \hat{\kappa}-k^{2}\right)}{3 i^{2}+4 \dot{c}^{2}\left(h^{2}+k^{2}+h k\right)} \\
& \cos Z \text { (basal) } \quad=\frac{4 \dot{c}^{2}\left(h^{2}+k^{2}+h k\right)-3 i^{2}}{3 i^{2}+4 \dot{c}^{2}\left(h^{2}+k^{2}+h k\right)^{\circ}}
\end{aligned}
$$

(c) Dihexagonal Prism [hki0],

$$
\begin{aligned}
& \cos \mathrm{X} \text { (axial) }=\frac{\hbar^{2}+k^{2}+4 h k}{2\left(h^{2}+k^{2}+h k\right)} \\
& \cos \mathrm{Y}(\text { diagonal })=\frac{2 k^{2}+8 h k-\pi^{2}}{2\left(h^{2}+k^{2}+h k\right)^{2}}
\end{aligned}
$$

(d) Rhombohedron $\kappa[0 h \hbar i]$,

$$
\cos X(\text { terminal })=\frac{3 i^{2}-2 \hbar^{2} \dot{c}^{2}}{3 i^{2}+4 \dot{c}^{2} h^{2}}
$$

(e) Scalenohedron $\kappa[h k T \bar{l}]$,

$$
\begin{aligned}
& \cos X(\text { see } f .800)=\frac{3 i^{2}+2 \dot{c}^{2}\left(2 h^{2}+2 h k-k^{2}\right)}{3 i^{2}+4 \dot{c}^{2}\left(h^{2}+k^{2}+h k\right)} \\
& \cos Y(\text { see } f .800)= \\
& \frac{3 i^{2}+2 \dot{c}^{2}\left(2 k^{2}+2 h k-i^{2}\right)}{3 i^{2}+4 \dot{c}^{2}\left(h^{2}+k^{2}+h k\right)} \\
& \cos Z(\text { basal }) \\
& =\frac{2 \dot{c}^{2}\left(k^{2}+k^{2}+4 h k\right)-3 i^{2}}{3 i^{2}+4 \dot{c}^{2}\left(h^{2}+k^{2}+h k\right)}
\end{aligned}
$$

(4) Relations of planes in a zone.-The general equation (3, p. 446) is to be employed For the pyramidal zones passing through the pole (0001) it takes a simpler form, viz. ${ }^{\circ}$

$$
\frac{h}{p}=\frac{k}{q}=\frac{i}{t} \cdot \frac{\tan \mathrm{PC}}{\tan \mathrm{QC}}
$$

If $\mathbf{Q}=(01 \overline{1} 1)$, then :

$$
\frac{\tan \mathrm{PC}}{\tan Q C}=\frac{k}{i} .
$$

Determination of the axis $\dot{c}$. -The value of $\dot{c}$ may be determined from any one of the equations which have been given. The following are simple cases :

$$
\tan (\hbar \hbar 2 \hbar 2 i)(0001)=\frac{i \hbar}{i} .
$$

Also $\tan (0 \pi \hbar i)(0001) \cdot \sin 60^{\circ}=\frac{i \hbar}{i}$, or $\tan (01 \overline{1} 1)(0001) \cdot \sin 60^{\circ}=\delta_{\text {. }}$

## IV. Orthoriombic System.

The Orthorhombic System is characterized by three unequal rectangular axes, $c, \bar{b}, a_{0} . *$ The indices $h, k, l$ may be either plus or minus, in the general form [ $h k l$ ], but they are not exchangeable, since they refer to axes of different lengths. This general symbol then embraces the following planes:

| $(h k l)$ | $(\bar{h} k l)$ | $(\bar{k} \bar{k} l)$ | $(h \bar{k} l)$ |
| :--- | :--- | :--- | :--- |
| $(h k \bar{k})$ | $(\bar{h} k l)$ | $(\bar{k} \bar{l} \bar{l})$ | $(h \bar{k} \bar{l})$ |

As different values are given to $h, k, l$, this general form becomes more or less specialized. The possible forms are as follows:

1. $\left\{\begin{array}{l}{[h k l] ; h>k .} \\ {[k h l] ; h>k .} \\ {[h h l] ; h=k .}\end{array}\right.$
2. $[h 0 l] ; k=0$.
3. $[0 k t] ; h=0$.
4. $\left\{\begin{array}{l}{\left[\begin{array}{l}h k 0] ; l=0, h>k . \\ {[k h 0] ; l=0, h>k .} \\ {[110] ;} \\ {[ }\end{array}=k=1, l=0 .\right.}\end{array}\right.$
5. $\quad[100] ; k=l=0$.
6. $\quad[010] ; h=l=0$.
7. $\quad[001] ; h=k=0$.

| $\breve{a}: n \bar{b}: m \dot{c}$ | [ $m-\bar{n}$ ] |
| :---: | :---: |
| $n \check{a}: \bar{b}: m \dot{c}$ | [ $m-n /$ |
| $\breve{a}: \bar{b}: m \dot{c}$ | [ $m$ ]. |
| $\check{a}: \infty \bar{b}: m \dot{c}$ | [ $m-\bar{i}$ ]. |
| $\infty \check{a}: \bar{b}: m \dot{c}$ | [ $m$ - $\boldsymbol{i}$ ]. |
| $\check{a}: n \bar{b}: \infty \dot{c}$ | [ $i-\bar{n}]$. |
| $n \check{a}: \bar{b}: \infty \dot{c}$ | [i-n̆]. |
| $\breve{a}: \bar{b}: \infty$ | [ 1 ]. |
| $\breve{a}: \infty$ b $: \infty$ | [ $i$ i- $\overline{\text { ] }}$. |
| $\infty \check{d}: \bar{b}: \infty \dot{c}$ | [ $i-2]$. |
| $\infty \breve{a}: \infty \bar{b}: \dot{c}$ | [0]. |

These symbols belong to the various distinct forms of this system, as follows :
Pinacoids.-(a) Basal plane. Symbol [001], including the two planes (001) and (001). (b)
Macropinacoid. Symbol [100], including the plane [100], and [100] opposite to it. (c)
Brachypinacoid. Symbol [010], including the planes [010] and [010].
Prisms,-( $\alpha$ ) Unit prism (1). Symbol 110, including four planes, (110), (110), (ī10), (1ī0).
(b) Macrodiagonal and brachydiagonal prisms, having respectively the symbols [ $\pi k 0$ ] and [ $k h 0$ ], if $h$ is greater than $k$. Thus the symbol $i-\overline{2}$ corresponds to [210], and $i-2$ to [120].

Domes.- (a) Macrodiagonal, or macrodomes. having the symbol [ $h 00$ ]; and (b) brachydiagonal, or brachydomes, with the symbol $[0 \mathrm{kl}]$. In each case the symbol embraces four similar planes.

Octahedrons or Pyramids.-The symbol [ $h h l]$ belongs to the eight planes of the unit pyramids, all lying in the zone between the unit prism [110], and the base [001]. If $h=l$ the form is then [111], and the eight planes are: (111), (111), ( $\overline{1} 11$ ), ( $1 \overline{1} 11$ ), ( $11 \overline{1} \overline{1}$ ), ( $\overline{1} 1 \overline{1}),(\overline{1} \overline{1} \overline{1}),(1 \overline{1} \overline{1})$.
of the general pyramids two cases are possible, either [ $h k i$ ] or [ $k h l$ ], when $h>k$, these correspond respectively to the prisms [ $k k 0$ ] and [ $k: h 0]$. They are the macrodiagonal and brachydiagonal pyramids of Naumann; thus $2-\overline{2}(=\breve{a}: 2 \overline{2}: 2 \dot{c})$
 is [211], according to Miller, and $2-\check{2}(=2 \breve{a}: \bar{b}: 2 \dot{c})$ is [121].

[^58]For the figures of the above-mentioned forms see pp. 42-44. Their relations will be understood from an examination of f. 801, showing the projection of the crystals in f. 758 , p. 444. It will be seen that all the macrodiagonal planes lie between the zonal circles (diameters) $(110)(001)$, and $(100)(001)$, and the brachydiagonal planes between $(110)(001)$ and $(010)(001)$.

## Mathematical Relations of the Orthorhombic System.

(1) For the distance between the pole of any plane $\mathrm{P}(h k l)$ and the pinacoid planes we have in general :

$$
\begin{aligned}
& \cos ^{2} \mathrm{PA}=\cos ^{2}(h k l)(100)=\frac{h^{2} b^{2} c^{2}}{h b^{2} c^{2}+k^{2} a^{2} c^{2}+l^{2} a^{2} b^{2}} \\
& \cos ^{2} \mathrm{~PB}=\cos ^{2}(h k l)(010)=\frac{k^{2} a^{2} c^{2}}{h^{2} b^{2} c^{2}+k^{2} a^{2} c^{2}+l^{2} a^{2} b^{2}} \\
& \cos ^{2} \mathrm{PC}=\cos ^{2}(h k l)(001)=\frac{l^{2} a^{2} b^{2}}{h^{2} b^{2} c^{2}+k^{2} a^{2} c^{2}+l^{2} a^{2} b^{2}}
\end{aligned}
$$

(2) For the distance $(\mathrm{PQ})$ between the poles of any two planes ( $h k l$ ) and ( $p q r$ ):

$$
\cos \mathrm{PQ}=\frac{h p b^{2} c^{2}+k q a^{2} c^{2}+l r a^{2} b^{2}}{\sqrt{\left[h^{2} b^{2} c^{2}+k^{2} a^{2} c^{2}+l^{2} a^{2} b^{2}\right]\left[p^{2} b^{2} c^{2}+q^{2} a^{2} c^{2}+r^{2} a^{2} b^{2}\right]}}
$$

(3) For planes lying in a zone, the general relation (p. 446) is to be employed. For the special cases, practically of most importance, the simplified equations which follow are used,
(4) To determine the lengths of the axes, the general equation may be employed :

$$
\frac{\breve{a}}{h} \cos \mathrm{PA}=\frac{\grave{b}}{\grave{k}} \cos \mathrm{~PB}=\frac{\dot{c}}{l} \cos \mathrm{PC}
$$

Here PA, PB, PC are the distances from the pole of any plane ( $k k l$ ) to the pinacoid planes (100), (010), (001) respectively. The brachydiagonal axis, $\check{a}$, is made the unit.

If the angle between any dome or prism and the adjoining pinacoid plane is given, the relations follow immediately :

$$
\begin{aligned}
& \tan \mathrm{PA}=\tan (h k 0)(100)=\frac{\grave{a} k}{b h} \\
& \tan \mathrm{~PB}=\tan (0 k l)(010)=\frac{b \tau}{c k} \\
& \tan \mathrm{PC}=\tan (h 0 l)(001)=\frac{i \hbar}{\bar{d}}
\end{aligned}
$$

## จ. Monoclintc System.

In the Monoolinic System there are three unequal axes, and one of these makes an oblique angle with a second. The axes are lettered as shown in f. 802,
 $\dot{c}$ is vertical, $b$ the orthodiagonal axis, and $d$ the clinodiagonal axis oblique to $\dot{c}$, but at right angles to $b$. The symbol [ $h k l$ ] embraces only four similar planes in the most general case, for in consequence of the obliquity of one of the axes, tho quadrants above in front correspond alone to those below and bshind, and those above behind correspond to those below in front. This is seen clearly in the projection of f. 803. For $\pm h, \pm k, \pm l$ the symbol [ $h k l]$ includes $t w o$ distinct forms, viz.
and
(1) $(\hbar k k)$
(hāt
$\begin{array}{ll}(\hbar k i) & \left.(\hbar k)^{\prime}\right) \\ (\hbar k i) & (h \hbar i,\end{array}$

The various form are as follows:

Pinacoids.-Base [001]. Orthopinacoid [100]. Clinopinacoid [010]. Each symbol, of course, comprehending two planes only.

803


801


Crocoite.

Prisms.-(a) Unit prism [110], $=\dot{d}: b: \infty \dot{c}(I)$ of Naumann. This symbol embraces four similar prismatic planes. (b) Orthodiagonal prisms [ $h k 0]$, where $h>k$, the poles of these prisms fall on the prismatic zonal circle between 100 and 110 (see f. 803). They correspond to the prisms $i-n(=d: n \dot{b}: \infty \dot{c}$ ) of Naumann. (c) Clinodiagonal prisms. Symbol [ $k h 0$ ], $h>k$, lying between (110) and (010). They correspond to $i-n(=n d: b: \infty \dot{c}$ ) of Naumann.

Domes.-(a) Hemi-orthodomes, including two cases, (101) and (101), the minus domes of Naumann (opposite the obtuse angle) ; and also ( $\overline{1} 01$ ) and ( $10 \overline{1}$ )), the plus domes of Naumann (opposite the acute angle $\beta$ ). (b) Clinodomes. Symbol [ $0 k l$ ], embracing four similar planes (0 $\mathrm{Fl} l)(0 \bar{k} l),(0 k \bar{l}),(0 \bar{k} \bar{l})$. The clinodome [011], equivalent to $1-i \quad(=\infty d: b: m \dot{3})$, is one case in this form.

Pyramids. - The pyramids are all hemi-pyramids. (a) The symbol [hhl] includes the unit pyramids in a zone between [110] and [001]. (b) The symbol [hkl] includes two sets of hemipyramids, whose indices have been given on p. 416, corresponding respectively to --P and +P of Naumann.

If $h$ is greater than $k$ these are orthodiagonal pyramids, corresponding to $\pm(\alpha: n b: \infty \dot{c})$ of Naumann. The symbol [ $k h l]$ on the same supposition includes two sets of planes, like those of p. 453, and differing only in being clinodiagonal; equivalent to ( $n d: b: \infty c$ ) of Naumann.

The orthodiagonal planes lie between the zone (100), (001) and (110), (001), while the clinodiagonal are between the latter zone and (010)(001), as is seen on f. 803 , which gives the projection for f. 804.

## Mathematical Relations for the Monoclinic System.

(1) The distances of the pole of any plane ( $k k l$ ) from the pinacoid planes are given by the f(llowing equations:

$$
\begin{aligned}
& \cos \mathrm{PA}=\cos (h k l)(100)=\sqrt{\frac{h b c+l a b \cos \beta}{h^{2} b^{2} c^{2}+k^{2} a^{2} c^{2} \sin ^{2} \beta+l^{2} a^{2} b^{2}+2 h l a b^{2} c \cos \beta}} ; \\
& \cos \mathrm{PB}=\cos (h k l)(010)=\sqrt{\frac{k a c \sin \beta}{h^{2} b^{2} c^{2}+k^{2} a^{2} c^{2} \sin ^{2} \beta+l^{2} a^{2} b^{2}+2 h l a b^{2} c \cos \beta}} ; \\
& \cos \mathrm{PC}=\cos (h k l)(001)=\sqrt{\frac{l a b+h b c \cos \beta}{h^{2} b^{2} c^{2}+k^{2} a^{2} c^{2} \sin ^{2} \beta+l^{2} a^{2} b^{2}+2 h l a b^{2} c \cos \beta}}
\end{aligned}
$$

(2) The distance between any two planes may be 3xpressed in general form, but in all practically arising eases the end can be attained by the solution of one or more spherical triangles on the projection.
(3) For the relation between the planes in a zone the general equation before given holds good:

$$
\frac{\cot P S-\cot P R}{\cot P Q-\cot P R}=\frac{(P Q) \cdot(S R)}{(Q R) \cdot(P S)^{\circ}}
$$

(4) For all zones passing through the clinopinacoid (010), the value of PR may be taken as $90^{\circ}$, and the above equation consequently simplified :

$$
\frac{\pi}{p}=\frac{k}{q} \cdot \frac{\tan \mathrm{~PB}}{\tan \mathrm{QB}}=\frac{l}{r}
$$

This equation is especially valuable for determining the indices of planes in the prismatio and clinodome series.
(5) To determine the axial relations the general equation admits of being transformed so as to read:
and

$$
\begin{array}{ll}
\frac{k}{l} \cdot & \frac{\sin \mathrm{PYA}}{\sin \mathrm{PYC}}=\frac{p}{r} \cdot \\
\frac{\sin \mathrm{QYA}}{\sin \mathrm{QYC}}=\frac{a}{c} ; \\
\frac{\sin \mathrm{PYA}}{\cot }=\frac{q}{r} \cdot & \frac{\sin \mathrm{QYA}}{\cot \mathrm{QY}}=\frac{b}{c} .
\end{array}
$$

The angles PYA, PYC are angles which may be calculated directly by spherical triangles from the measured angles. Similarly for QYA, QYC. PY and QY are the angles between the given plane $\mathbf{P}$ or $\mathbf{Q}$ with the clinopinacoid.

## VI. Triclinic System.

In the Triclinic $£ y s t e m$, since the axes are unequal and all mutually oblique, there can be no plane of symmetry, and there can in no case be more than two planes included in a single form. The three axes are distinguished as a vertical, $\dot{c}$, a longer lateral, or macrodiagonal axis, $\bar{b}$, and a shorter lateral, or brachydiagonal axis, $\check{a}$. The position assumed for the axes is shown in f. 259, p. 80.

The general symbol [ $h k l]$, which includes eight similar planes in the orthorhombic system, is here resolved into four independent forms, embracing two opposite planes only. They are thus:

$$
\begin{array}{lll}
\text { (1) } \begin{array}{l}
(h k l) \\
(\bar{h} \bar{k})
\end{array} & \text { (2) } \begin{array}{l}
(h \bar{k} l) \\
(\bar{h} k l)
\end{array} & \text { (3) } \left.\begin{array}{l}
(h k \bar{l}) \\
(\bar{k} \bar{k} l)
\end{array}\right)
\end{array}
$$

These correspond respectively to $m \mathrm{P}^{\prime} n$ (1), $m^{\prime} \mathrm{P} n$ (2), $m \mathrm{P}, n$ (3), $m, \mathrm{P} n$ (4) of Naumann, on $-m-n,-m \cdot n, m-n^{\prime}, m-n^{\prime}$, as the abbreviated symbols are written in the earlier part of this work.

Contrary to the usage in the orthorhombic system, it is customary to make [100] the macropinacoid ( $i-\bar{\imath}=\bar{u}: \infty \bar{b}: \infty \dot{c}$ ), and [010] the brachypinacoid $(i-\bar{\imath}=\infty \bar{a}: b: \infty c c$. Planes having the symbol $[400]$ are then macrcdoness; and those of the symbol [0kl] are brachydomes. Similarly then pyramids $(h>k)$ of the form [ $h k l]$ are macrodiagonal planes, and those of the form ( $(k k l)$ are brachydiagonal planes. The unit prism consists of two independent forms (110), (110) ( $\left.\mathrm{I}^{\prime}=\infty \mathrm{P},{ }^{\prime}\right)$, and (110), (110) $\left(\mathrm{I}=\infty^{\prime}, \mathrm{P}\right)$.

## Mathematical Relations of the Triclinic System.

In consequence of the obliquity of the axes in the Triclinic System the mathematical relations are less simple, aud the general equations deduced as before become so complicated as to be seldom of much practical value. Most problems which arise may be solved by the zonal relations, or by the solution of the spherical triangles in the projection. Some of the most important relations (given by Schrauf) are as follows:

If the angle between the axes X and $\mathrm{Z}=\eta$, between X and $\mathrm{Y}=\zeta$, and betwuen Y and $\boldsymbol{\lambda}$ $=\xi$ (see f. ${ }^{757}$ ) ; if also $\alpha, \beta, \gamma$ are the corresponding angles between the pinacoid planesthen.
$\cos \xi=\frac{\cos \beta \cos \gamma-\cos \alpha}{\sin \beta \sin \gamma}, \quad \cos \eta=\frac{\cos \gamma \cos \alpha-\cos \beta}{\sin \gamma \sin \alpha} . \quad \cos \zeta=\frac{\cos \beta \cos \alpha=\cos \eta}{\sin \alpha \sin \beta}$
and $\quad \cos ^{2} \mathrm{PX}=\frac{l^{2} b^{2} c^{2} \mathrm{~A}_{1}}{\mathrm{M}_{1}} . \quad \cos ^{2} \mathrm{PY}=\frac{k^{2} a^{2} c^{2} \mathrm{~A}}{\mathrm{M}_{1}} . \quad \cos ^{2} \mathrm{PZ}=\frac{l^{2} a^{2} b^{2} \mathrm{~A}_{1}}{\mathrm{M}_{1}}$
where

$$
\begin{aligned}
\mathrm{A}_{1} & =\left[1+2 \cos \alpha \cos \beta \cos \gamma-\left(\cos ^{2} \alpha+\cos ^{2} \beta+\cos ^{2} \gamma\right)\right] \\
\mathrm{M}_{1} & =h^{2} b^{2} c^{2} \sin ^{2} \alpha+k^{2} a^{2} c^{2} \sin ^{2} \beta+l^{2} a^{2} b^{2} \sin ^{2} \gamma+2 a b c(h l b \cos \beta \sin \alpha \sin \gamma \\
& +h k c \cos \gamma \sin \alpha \sin \beta+k l a \cos \alpha \sin \beta \sin \gamma) .
\end{aligned}
$$

Also

$$
\cos ^{2} A X=\frac{A_{1}}{\sin ^{2} \alpha} ; \quad \cos B Y=\frac{A_{1}}{\sin ^{2} \beta} ; \quad \cos C Z=\frac{A_{1}}{\sin ^{2} \gamma}
$$

When PX, PY, PZ have been found by calculation, then the following equation gives the relation of the axes:

$$
\frac{a}{h} \cos \mathrm{PX}=\frac{b}{k} \cos \mathrm{PY}=\frac{c}{l} \cos \mathrm{PZ}
$$

As seen in f. 805.
$\cos \mathrm{PX}=\sin \mathrm{PBC} \sin \mathrm{PB}=\sin \mathrm{PCB} \sin \mathrm{PC} ;$ $\cos \mathrm{PY}=\sin \mathrm{PCA} \sin \mathrm{PC}=\sin \mathrm{PAC} \sin \mathrm{PA}$; $\cos \mathrm{PZ}=\sin \mathrm{PAB} \sin \mathrm{PA}=\sin \mathrm{PBA} \sin \mathrm{PB} ;$ and also from these it follows that-

$$
\begin{aligned}
& \frac{b}{h} \sin \mathrm{PAC}=\frac{c}{l} \sin \mathrm{PAB} \\
& \frac{c}{l} \sin \mathrm{PBA}=\frac{a}{h} \sin \mathrm{PBC} \\
& \frac{a}{h} \sin \mathrm{PCB}=\frac{\dot{b}}{h} \sin \mathrm{PCA}
\end{aligned}
$$



$$
\xi=180^{\circ}-\mathrm{CAB} ; \quad \eta=180^{\circ}-\mathrm{ABC}
$$

## Refations of the Six Crystalline Systems in Respect to Symmetry.

From a careful study of the spherical projections for the successive systems a very cleax idea may be obtained of the degree of symmetry which characterizes each. It is well understood that in the Isometric System there are nine planes of symmetry ; in the Tetragonal, five; in the Hexagonal, seven ; in the Orthorhombic, three; and in the Monoclinic only one. These relations are shown on the projections by the symmetrical distribution of the poles abort the respective great circles. These zone-circles of symmetry are as follows:

Isometric System (f. 766) : 1st, the three diametral zones:

1. $(100),(010),(\overline{1} 00)$.
2. (100), (001), ( $\overline{1} 00$ ).
3. $(010),(001),(0 \overline{1} 0)$.

Also the diagonal zones:
4. (110), (001), ( $\overline{1} 10)$.
6. (100), (011), (100).
8. $(010),(101),(0 \overline{1} 0)$.
5. (110), (001), (110).
7. (100), (011), (100).
9. (010), ( $\overline{1} 01$ ), ( $0 \overline{1} 0)$.

Tetragonal System (f. 790) :

1. $(100),(010),(\overline{1} 00)$.
2. $(100),(001),(\overline{1} 00)$.
3. (010), (001), (010).

## Also :

$$
\text { 4. }(110),(001),(\overline{1} 10) . \quad \text { 5. }(1 \overline{1} 0),(001),(\overline{1} 10) \text {. }
$$

Hexugonal System (f. 793):

1. $(10 \overline{1} 0),(0001),(\overline{1} 010)$.
2. (11 $\overline{2} 0),(0001),(\overline{1} 120)$.
3. (0110), (0001), (01̄10).
4. ( $\overline{12} \overline{1} 0),(0001),(1 \overline{2} 10)$.
5. (1010), (0110), ( $\overline{1} 100$ ).
6. $(\overline{1} 100),(601),(1 \overline{1} 00)$.
7. ( $\overline{11} 10),(0001),(2 \overline{1} 10)$.
8. (010), (001), (010).
9. (100), (001), (100).

Oithorhombic System (f. 801) :

1. (100), (010), (100).

Monoclinic System (f. 804) :

1. $(100),(001),(\overline{100})$.

In the Triclinic System there is no plane of symmetry.

Tife Rhombohfdral Division of Miller.
The following projection (f. 806) is added in order to show the relation of the forms in the Hexagonal and Rhombohedral Systems as
 referred to the three equal oblique axes of Miller. The forms are as follows:

The planes having the indices (100), (010), (001) are those of the (plus) fundamental rhombohedron, while the plane (111) is the base. The planes (221), (121), (122) are those of the minus fundamental rhombohedron; with the planes (100), (010), (001) they form the unit hexagonal pyramid.

The hexagonal unit prism ( $I=[01 \overline{1} 0]$ ) has the symbols: (21i), (1 $\overline{1} 1),(\overline{1} 2),(\overline{2} 11)$, (12ī), (112̄). The second, or diagonal hexagonal prism $(i-2=[11 \overline{2} 0])$ has the symbols : (101), (110), (011), (101), (110), (011).

The dihexagonal pyramid embraces, like the simple hexagonal pyramid, two forms, [ lkl l$]$ and [efg]; the symbol [ hkl$]$ hence belongs to the plus scalenohedron, and $[e f g]$ to the minus. In this as in other cases it is true that: $e=-h+2 k+2 l$, $f=2 h-k+2 l, g=2 k+2 k-l$.
The dihexagonal prism includes the six planes of the form [ $h k 0$ ], and the remain-
ing six of the form [ef 0 ].
Most of the problems arising under this system can be solved by the zone exuations, or by the working out of the spherical triangles on the sphere of projection.

## APPENDIX B.

## ON THE DRAWING OF FIGURES OF CRYSTALS.

In the projection of crystals, the eye is supposed to be at an infinite distance, so that the rays of light fall from it on the crystal in parallel lines. The plane on which the crystal is projected is termed the plane of projection. This plane may be at right angles to the vertical axis, may pass through the vertical axis, or may intersect it at an oblique angle. These different positions give rise, respectively, to the horizontal, veritical, and oblique projections. The rays of light may fall perpendicularly on the plane of projection, or may be obliquely inclined to it; in the former case the projection is termed orthographic, in the second clinograpiric. In the horizontal position of the plane of projection, the projection is always orthographic. In the other positions, it may be either orthographic or clinographic. It is generally preferable to employ the vertical position and clinographic projection, and this method is elucidated in the following pages.

## Projection of the Axes.

The projection of the axes of a crystal is the first step preliminary to the projection of the form of the crystal itself. The projection of the axes in the isometric system, which are equal and intersect at right angles, is here first given. The projection of the axes in the other systems, with the exception of the hexagonal, may be obtained by varying the lengths of the projected isometric axes, and also, when oblique, their inclinations, as shown beyond.

Isometric Systcm. - When the eye is directly in front of a face of a cube, neither the sidee nor top of the crystal are visible, nor the planes that may be situated ou the intermediate edges. On turning the crystal a few degrees from right to left, a side lateral plane is brought in view, and by elevating the cye slightly, the terminal plane becomes apparent. In the following dem-onstration, the angle of revolution is designated $\delta$, and the angle of the elevation of the eye, $\epsilon$. Fig. 807 represents the normal position of the horizontal axes, supposing the eye to be in the direction of the axis $B B ; B B$ is seen as a mere point, while CC appears of its actual length. On revolving the whole through a number of degrees equal to $\mathrm{BMB}^{\prime}$ ( $\delta$ ) the axes have the position exhibited in the dotted lines. The projection of the semiaxis MB is now lengthened to MN, and that of the semiaxis MC is shortened to MH.

If the eye be elevated (at any angle, $\epsilon$ ), the lines $\mathrm{B}^{\prime} \mathrm{N}, \mathrm{BM}$,
 and $\mathrm{C}^{\prime} \mathrm{H}$ will be projected respectively below $\mathrm{N}, \mathrm{M}$, and H , and the lengths of these projections (which we may designate $b^{\prime} \mathrm{N}, b \mathrm{M}$, and $c^{\prime} \mathrm{H}$ ) will be directly proportional to the lengths of the lines $\mathrm{BN}, \mathrm{BM}$, and $\mathrm{C}^{\prime} \mathrm{H}$.

It is usual to adopt such a revolution and such an elevation of the eye as may be expressed by a simple ratio between the projected axes. The ratio between the two axes, MN : MII. as projected after the revolution, is designated by $1: r$; and the ratio of $b^{\prime} N$ to MN by $1: s$ Suppose $r$ to equal 3 and $s$ to equal 2 , then proceed as follows:

Draw two lines $\mathrm{AA}^{\prime}, \mathrm{H}^{\prime} \mathrm{H}\left(\right.$ f. $\left.^{\prime} 808\right)$, intersecting one another at right andles. Make MH =
 $\mathrm{MH}^{\prime}=b$. Divide $\mathrm{HH}^{\prime}$ into $3(r)$ parts, and through the points, $\mathrm{N}, \mathrm{N}^{\prime}$, thus determined, draw perpendiculars to HH'. On the left hand vertical, set off, below H', a part $H^{\prime} \mathrm{R}$, equal to $\frac{1}{s} b=\frac{1}{2} \mathrm{H}^{\prime} \mathrm{M}$; aud from R draw RM, and extend the same to the vertical $\mathrm{N}^{\prime}$. B B is the projection of the front horizontal axis.

Draw BS parallel with $\mathrm{MH}^{\prime}$ and connect SM. From the point $T$ in which SM intersects BN, draw TC parallel with MH. A line ( $\mathrm{CC}^{\prime}$ ) drawn from C through M, and extended to the left vertical, is the projection of the side horizontal axis.
Lay off on the right vertical, a part HQ equal tc $\frac{1}{3} \mathrm{MH}$, and make $\mathrm{MA}=\mathrm{MA}^{\prime}=\mathrm{MQ} ; \mathrm{AA}^{\prime}$ is the vertical axis. If, as here, $r=3$, and $s=2$, then $\delta=18^{\circ} 26^{\prime}$, and $\epsilon=9^{\circ} 28^{\prime}$, for $\cot \delta=r$, and $\cot \epsilon=1$ 's.
Tetragonal and Orthorkombic Systems.-The axes AA', CC', BB, constructed in the mannex described, are equal and at right angles to each other. The projection of the axes of a tetragonal crystal is obtained by simply laying off, with a scale of proportional parts, on MA and MA' taken as units, the value of the vertical axis (c) for the given species. Thus for zircon, where $\dot{c}={ }^{\cdot 64}$, we must lay off 64 of MA above M and the same length below.

For an orthorhombic crystal, where the three axes are unequal, the length of $\dot{c}$ must as before be laid off above and below from M, and that of $\bar{b}$ to the right and left of $M$, on CC', MC being taken as the unit. It is usual to make the front axis MB $=\breve{u}=1$.

Monoclinic System.-The axes $\dot{c}$ and $\grave{a}$ in the monoclinic system are inclined to one another
 at an obliqe angle $=\beta$. To project this inclination, and thus adapt the isometric axes to a monoclinic form, lay off (f. 809) on the axis MA, M $t=\mathrm{MA} \cos \beta$, and on the axis $\mathrm{BB}^{\prime}$ (before or behind M, according as the inclination of $\dot{a}$ on $\dot{c}$, in front, is acute or obtuse) $\mathrm{M} b=\mathrm{MB} \times \sin \beta$. From the points $b$ and $a$, draw lines parallel respectively with the axes $\mathrm{AA}^{\prime}$ and $\mathrm{BB}^{\prime}$, and from their intersection $\mathrm{D}^{\prime}$, draw through $\mathrm{M}, \mathrm{D}^{\prime} \mathrm{D}$, making $\mathrm{MD}=\mathrm{MD}^{\prime}$. The lin $\epsilon$ $\mathrm{DD}^{\prime}$ is the clinodiagonal, and the lines $\mathrm{AA}, \mathrm{C}^{\prime} \mathrm{C}, \mathrm{DD}^{\prime}$ represent the axes in a monoclinic solid in which $a=b=c$ $=1$. The points $a$ and $b$ and the position of the axis DD' will vary with the angle $\beta$. The relative values of the axes may be given them as above explained; that is, if $\dot{a}=1$, lay off in the direction of MA and MA' a line equal to $\dot{c}$, and in the direction of MC and $\mathrm{MC}^{\prime}$ a line equal to $b$, etc.

Triclinic System.-The vertical sections through the horizontal axes in the triclinic system are obliquely inclined; also the inclination of the axis $a$ to each axis $b$ and $c$, is oblique. In the adaptation of the isometric axes to the triclinic forms, it is therefore necessary, in the first place, to give the requisite obliquity to the mutual inclination of the vertical sections, and afterwards to adapt the horizontal axes. The inclination of these sections we may designate A , and as heretofore, the angle between $a$ an $b, \gamma$, and $a$ and $c, \beta$. $\mathrm{BB}^{\prime}$ is the analogue of the brachydi gonal, and CC of the macrodiagonal. An obligue inclination may be given the vertical sections, by varying the position of either of these sections. Permitting the brachydiagonal section $\mathrm{ABA}^{\prime} \mathrm{B}^{\prime}$ to remain unaltered, we may vary the other section as follows:

Lay off (f. 810) on MB, M $b^{\prime}=\mathrm{MB} \times \cos \mathrm{A}$, and on the axis C C (to the right or left of M, according as the acute angle A is to the right or left), $\mathrm{Mc}=\mathrm{MC} \times \sin \mathrm{A}$; completing the parallelogram $\mathrm{M} b^{\prime} \mathrm{D} c$, and drawing the diagonal MD, extending the same to $\mathrm{D}^{\prime}$ so as to make MD - MD, we obtain the line $\mathrm{DD}^{\prime}$, the vertical section
passing through this line is the correct macrodiagonal section. The inclination of $a$ to the new macrodiagonal $\mathrm{DD}^{\prime}$ is still a right angle; as also the inclination of $a$ to $b$, their oblique inclinations may be given them as follows: Lay off on MA (f. 810), Ma=MA $a \cos \beta$, and on the axis $\mathrm{BB}^{\prime}$ (brachydiagonal), $\mathrm{Mb}=\mathrm{MB}^{\prime} \times \sin \beta$. By completing the parallelogram $\mathrm{M} a$. $\mathrm{E}^{\prime}$ b, the point $\mathrm{E}^{\prime}$ is determined. Make ME=ME; EE is the projected brachydiagonal. Again lay off on MA, M $a^{\prime}=\mathrm{MA} \times \cos \alpha$. and on $\mathrm{MD}^{\prime}$, to the left. $\mathrm{M}\left(l=\mathrm{MD}^{\prime} \times \sin \alpha\right.$. Draw lines from $a^{\prime}$ and $d$ parallel to MD and MA; $F^{\prime}$, the intersection of these lines, is one extremity of the macrodiagonal; and the line $\mathrm{FF}^{\prime}$, in which $\mathrm{MF}=\mathrm{MF}^{\prime}$, is the macrodiagonal. The vertical axis $\mathrm{AA}^{\prime}$ and the horizontal axes $\mathrm{EE}^{\prime}$ (brachydiagonal) and $\mathrm{FF}^{\prime}$ (macrodiagonal) thus obtained, wre the axes in a triclinic form, in which $a=b=c=1$. Different values may be given these axes, according to the method heretofore illustrated.

Hexagonal System.-In this system there are three equal horizontal axes, at right angles to the vertical axis. The normal position of the horizontal axes is represented in f. 811. The eye, placed in the line of the axis YY, observes two of the semiaxes, MZ and MU, projected in the same straight line, while the third, MY, appears a mere point. To give the axes a more eligible position for a representation of the various planes on the solid, we revolve them from right to left through a certain number of degrees $\delta$, and elevate the eye at an angle $\epsilon$. The dotted lines in the figure represent the ax¢s in their new situation, resulting from a revolution through a number of degrees equal to $\delta=$ YMY'. In this position the axis MY is projected upon MP, MU' upon MN, and MZ' on MH. Dєs gnating the intermediate axis I, that to the right II, that to the left III, if the revolution is such as to give the projections of I and II the ratio of $1: 2$, the relations of the three projections will be as follows : I: II : III $=1: 2: 3$.
Let us take $r$ ( $=$ PM : HM) equal to 3 , and $s\left(=b^{\prime} \mathrm{P}\right.$ :
 PM) equal to 2 , these being the most convenient ratios for representing the hexagonal crystalline forms. The following will be the mode of construo tion :

1. Draw the lines AA, HH (f. 812) at right angles with, and bisecting, each other. Let $\mathrm{HM}=b$, or $\mathrm{HH}=2 b$ Divide HH into six parts by vertical lines. These lines, including the left- and right-hand verticals, may be numbered from one to six, as in the figure. In the first vertical, below $H$, lay off $H S=\frac{1}{2} b$, and from $S$ draw a line through $M$ to the fourth vertical. $\mathrm{YY}^{\prime}$ is the projection of the axis I .
2. From Y draw a line to the sixth vertical and parallel with HH. From T, the extremity of this line, draw a line to N in the second vertical. Then from the point $U$, in which TN intersects the fifth vertical, draw a line through $M$ to the second vertical ; $\mathrm{UU}^{\prime}$ is the projection of the axis II.
3. From R, where TN intersects the third vertical, draw RZ to the first vertical parallel with HH. Then from $Z$ draw a line through $M$ to the sixth vertical ; this line $Z Z^{\prime}$ is the projection of the axis III.
4. For the vertical axis, lay off from $N$ on the second vertical (f. 812) a line of any length, and construct upon this line an equilateral triangle ; one side (NQ) of this triangle will intersect the first vertical ut a distance, HV , from H, corresponding to ZH in f. 811 ; for in the triangle NHV, the angle HNV is an angle of $30^{\circ}$, and $\mathrm{HN}=\frac{1}{2} \mathrm{MH}$. MV is therefore the radius of the circle (f. 811). Make therefore $\mathrm{MA}=\mathrm{MA}^{\prime}=\mathrm{MV}$; $\mathrm{AA}^{\prime}$ is the vertical axis, and $\mathrm{YY}^{\prime}$,
 $\mathrm{UU}^{\prime}, \mathrm{ZZ}^{\prime}$ are the projected horizontal axes.
The vertical axis has been constructed equal to the horizontal axes. Its actual length in different hexagonal or rhombohedral forms may be laid off according to the method sufficiently explained.
The projection of the isometric and hexagonal axes, having been once accurately made, and that on a conveniently large scale, may be kept on a piece of cardboard, and will then answer all subsequent requirements. Whenever needed for use, these axes may be transferred to a sheet of paper, and then adapted in length, or inclination, or both, to the case in hand.

## Projection of tue Forms of Crystals.

- Simple forms. -When the axial cross has been constructed for the given species, the unit octahedron is obtained at once by joining the
 extremities of the axes, $\mathrm{AA}^{\prime}, \mathrm{BB}, \mathrm{CC}^{\prime}$, as in f. 813. Here as in all cases the lines which fall in front are drawn strongly, while those behind are simply dotted.

For the diametral prisms draw through B, B', C, C', of the projected axes of any species, lines parallel to the axes $\mathrm{BB}, \mathrm{CC}$ ', until they meet; they make the parallelogram, $a b c d$, which is a transverse section of the prism, parallel to the base. Through $a, b, c, d$ draw lines parallel and equal to the vertical axis, making the parts above and below these points equal to the vertical semiaxis. Then, connect the extremities of these lines by lines parallel to $a b, b c, c d, d a$, and the figure will be that of the diametral prism, corresponding to the axes projected.

In the case of the isometric system this diametral prism is the cube, whose faces are represented by the letter $H$; in the tetragonal system it is the prism $O, i-i$; in the orthorhombic, the prism $O, i-\bar{\imath}, i-\bar{\imath}$; in the monoclinic, the prism $O, i-i, i-\bar{\imath}$; in the triclinic, $O, i-\bar{\imath}, i-\bar{\imath}$.

The unit vertical prism in the tetragonal, orthorhombic, and clinometric systems may be projected by drawing lines parallel to the vertical axis $\mathrm{AA}^{\prime}$ through $\mathrm{B}, \mathrm{C}, \mathrm{B}^{\prime}, \mathrm{C}^{\prime}$, making the parts above and below these points equal to the vertical semiaxis; and then connecting the extremities of these lines by lines parallel to $\mathrm{BC}, \mathrm{CB}^{\prime}, \mathrm{B}^{\prime} \mathrm{C}^{\prime}, \mathrm{C} \mathrm{C}^{\prime}$. The plane $\mathrm{BCB} \mathrm{C}^{\prime}$ is a transverse section of such a prism parallel to its base. It is the prism $O, I$, in each of the systems excepting the triclinic, and in that $O, I, I^{\prime} ;$ a square prism in the tetrago $12 l$ system; a right rhombic in the orthorhombic; an oblique rhombic in the monoclinic; an oblique rhomboidal in the triclinic.
Other simple forms under the different systems are constructed in essentially the same way. It is only necessary to lay down upon the axes each plane of the form, in lightly drawn lines,

note the points where it intersects the adjoining planes, and draw these in more strongly. When the process is complete the construction lines may be erased. The process will be illustrated hy f. 814 and f. 815 . In the former case it is required to draw the trigonal trisoo tahedron, whose symbol is 2

In $f .814$ the three planes of the first octant are represented, they are 2:1:1, 1:2:1, and $1: 1: 2$. It wili be seen here, what is always true, that the two points of intersection required to determine the line of intersection, lie in the axial planes. These lines of intersection are represen'ed by the dotted lines in $f$. 814 . If the same prosess be performed for the other octants, the complete form, as in f .816 , will be obtained.

Similarly in f. $8: 5$, the octagonal pyramid $1-2$ is constructed; the figure shows the planea of one octant only, $\dot{c}: 2 a: a$, and $\dot{c}: a: 2 a$, and the dotted line gives their liņe of intersection. Carry out the same plane of construction in the other octants, and the torm of f .817 will result.

The construction of the various crystalline forms, by this method, especially those of the isometric system, will be found an interesting and instructive process, and will lead to a clear understanding of the forms themselves and their relations to each other. Another and quicker, though more mechanical mothod of constructing the isometric forms may also be giver.

Prijection of Simple Iscmetric Forms.-This method depends upon the principle that in the different isonetric forms the vertices of the solid angles are occupied by one or more of the interaxes (p. 16). If, therefore, these points (the extremitios of the interaxes), can be determined in the several crystalline forms, it is only necessary to connect them in order to obtain the projection of the solid itself.

As a preparation for the construction of figures of isometric crystals, it is desirable to have at hand the figure of a cube projected on a large scale, with its axes, and its trigonal (octahedral), and rhombic (dodecahedral) interaxes.

The values of the interaxes $t$ and $r$, for a given form, are obtained by adding to their normal length the values of $t^{\prime}$ and $r^{\prime}$ respectively given by the following equations; those of the octahedron being taken as a unit:

$$
t^{\prime}=\frac{2 m n-(m+n)}{m n+(m+n)} . \quad r^{\prime}=\frac{n-1}{n+1} .
$$

The proportion to be added to the interaxes for some of the common forms is as follows:

|  | ¢ | $r$ |  | $t$ |
| :---: | :---: | :---: | :---: | :---: |
| 2 | $\frac{1}{6}$ | 0 | $i-2$ | 1 |
| , | $\frac{1}{2}$ | 0 | $i$-3 | $\frac{5}{4}$ |
| 8-3 | $\frac{1}{2}$ | $\frac{1}{6}$ | 2-2 | $\frac{1}{2}$ |
| 4-2 | $\frac{8}{7}$ | $\frac{1}{8}$ | 3-3 | $\frac{4}{6}$ |

To construct the form 4-2, the octahedron is first to be projected, and its axes and interaxes drawn. Then add to each half of each trigonal interaxis, five-sevenths of its length; and to each half of each rhombic interaxis, one-third of its length. The extremities of the lines thus extended are situated in the vertices of the solid angles of the hexoctahedron 4-2, and by connecting them, the projection of this form is completed.

In the inclined hemihedral isometric forms (p. 20), the rhombic interaxes do not terminate in the vertices of the solid angles, and may therefore be thrown out of view in the projection of these solids. The two halves of each trigonal interaxis terminate in the vertices of dissimilar angles, and are of unequal lengths. One is identical with the corresponding interaxis in the holohedral forms. and is called the holohedral portion of the interaxis; the other is the hemihedral portion. The length of the latter may be determined by adding to the half of the octahedral interaxis that portion of the same indicated in the formula:

$$
\frac{2 m n-(m-n)}{m n+(m-n)}
$$

If the different halres of the trigonal interaxes be assumed at one time, as the holohedral, and again as the hemihedral portion, the reverse forms $\frac{(m-n)}{2}$ and $-\frac{(m-n)}{2}$ may be projected. The following table contains the values of the above fraction for several of the inclined hemihedral forms, and also the corresponding values for the holohedral portion of the interexis:

Hol. interax. Hem. interax.
Hol. interax. Hem. interax,

| $\frac{(1)}{2}(f .76$, p. 20) | 0 | 2 | $\frac{(2)}{1}(f .85)$ | $\frac{1}{6}$ | 1 |
| :--- | :--- | :--- | :--- | :--- | :--- |
| $\frac{(2-2)}{2}(f .81)$ | $\frac{1}{3}$ | 2 | $\frac{\left(3-\frac{3}{2}\right)}{2}(f .87)$ | $\frac{1}{3}$ | $\frac{5}{2}$ |
| $\frac{(3-3)}{2}$ | $t$ | 2 | $\frac{(4-2)}{2}$ |  |  |

The parallel hemihedrons (for example, the pentagonal dodecahedron, or hemi-tetrahexahe. dron) contain a solid angle, situated in a line between the extremities of each pair of semiaxes, which is called an unsymmetrical solid angle. The vertices of these angles are at unequal distances from the two adjacent axes, and therefore are not in the line of the rhombic interaxes. The co-ordinates of this solid angle for any form, as ${ }_{m}{ }^{[m-n]}$, may be found by the formulas $\frac{m(n-1)}{m n-1}$ and $\frac{n(m-1)}{m n-1}$. By means of these formulas, the situation of two points, $a$ and $b$ (f. 818), in each of the axes may be determined : and if lines are drawn through $a$ and $b$ in each semiaxis parallel to the other axes, the intersections $c c^{\prime}$, of these lines will be the vertices of the unsymmetrical solid angles, those marked $c$ of the form $\frac{[m-n]}{2}$ and those marked $s^{\prime}$ of the form $-\frac{[m-n]}{2}$.


The trigonal interaxes are of the same length as in the holohedral forms. The vanues of these interaxes, and of the coördinates of the unsymmetrical solid angle for different parallel hemihedrons, are contained in the following table:

|  | Trigonal interaxis. | Coōrd. of the unsym. S. A. |  | [ $i-\frac{3}{2}$ ] |  | Trigonal interaxis. | Coōrd. of the unsym. S. A. |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| $\frac{\left[3-\frac{3}{2}\right]}{2}($ f. 100, p. 23) | $\frac{1}{2}$ | $\frac{3}{7}$ | 9 |  | (sim. f. 92) | $\frac{4}{8}$ | $\frac{1}{8}$ | 1 |
| [4-2] | 4 | $\frac{4}{7}$ | $\frac{6}{7}$ | $\frac{[i-2]}{2}$ | (f. 92) | 1 | $\frac{1}{2}$ | 1 |

Projection of a Rhombohedron.-To construct a rhombohedron, lay off verticals tr ough the extremities of the horizontal axes, and make the parts both above and below these e ttremities equal to the third of the vertical semiaxis (f. 819). The points E, E, E', E, etc., are thus determined; and if the extremities of the vertical axis be connected with the poin:s E or $\mathrm{E}^{\prime}$, rhombohedrons in different positions, $m \mathrm{R}$, or $-m \mathrm{R}$, will be constructed.

Scalenohedron.-The scalenohedron $m^{n}$ admits of a similar construction with the rhombohe dron $m \mathrm{R}$. The only variation required, is to multiply the vertical axis by the number of units in $n$, after the points E and $\mathrm{E}^{\prime}$ in the rhombohedron $m \mathrm{R}$ have been determined; then connect the points E , or the points E ', with one another and with the extremities of the vertical axis.
2. Complex Forms.-When it is required to figure not only the planes of one form, that is, those embraced in one symbol, but also those of a number modifying one another, a somewhat different process is found desirable. It is possible indeed to construct a complex form in the way mentioned on p. 466, each plane being laid off on the given axes, and its intersec-tion-edges with adjoining planes determined by two points, always in the axial sections, which it has in common with each. In this way, however, the figure will soon become so complex as to be extremely perplexing, and thus lead to error and consequent loss of time.

This difficulty is in part avoided by the use of one projection of the axes on a larger scale, upon which the directions of the intersection-lines are determined, while a second smaller one,
placed below and parallel to it on the same sheet of paper, is used for the actual drawing of the crystal. In most cases, however, the crystal may be drawn as conveniently without the use of the second set of axes. The size of the figure may be either that which is to be finally required, or, more advantageously, it maybe drawn two or three times larger and then reduced hy photography. This method is especially to be recommended when the figures are finally to be engraved on wood, since from the enlarged drawing they may be photographed directly upon the wood of any required size, and thus a very high degree of accuracy attaincd.

Application of Quenstedt's Projection. - The process of determining the direction of the intersertion-edges is much simplified if the principles of Quenstedt's Projection (p. 55) are made use of. In other words, the symbol of every plane is so transformed that for it the length of the vertical axis is unity. This extremity of the vertical axis is then one point of intersection for all planes whatsoever, and the second point will always lie in the horizontal plane, that of the lateral axes. The change in the symbol requires nothing but that the symbol, expressed in full, should be divided by the coefficient of the vertical axis. The direction of each intersection-edge, when determined, is transferred to the figure in process of construction by means of a small triangle sliding against a ruler some 8 inches in length. it will be found in practice that, especially when this method is employed, it is not necessary to actually draw all the lines representing each plane, but to note simply the required points of intersection. This method and its advantages (see Klein, Einleitung in die Krystallberechnung, II., p. 387) will be made clear by an example.

It is required to project a crystal of andalusite of prismatic habit, showing also the planes $i-\overline{\tilde{L}}, i-\bar{i}, 1 \cdot i, 1,2-\check{2}, 1-\bar{i}$, and 0 .
It is evident that an indefinite number of figures may be made, including the planes mentioned, and yet of very different appearance according to the relative size of each. It is usually desirable, however, to represent the actual appearance of the crystal in nature, only in ideal symmetry, hence it is very important in all cases to have a sketch of the crystal to be represented, showing the relative development of the different planes. If this sketch is made with a little care, so as to show also the parallelism of the intersection-edges in the occurring zones, it will give material aid. The zones, it is to be noted, are a great help in drawing figures of crystals, and they should be carefully studied, since the common direction of the intersection-edge once determined for any two planes in it, will answer for all others.


The first step is to take the projection of the isometric axes already made once for all on a conveniently large scale, and which, as before suggested, is kept on a card of large size, and ready to be pierced through on to the paper employed. These axes, now of equal length, must be adapted to the species in hand. For andalusite the axial ratio is $\dot{c}: \bar{b}: \breve{u}=0,712$ : $1 \cdot 014: 1$; hence the vertical axis $\dot{c}$ must have a length 71 of what it now has, and the lateral axis one $1 \cdot 01$; these required lengths are determined in a moment with a scale of equal parts

The next step is to draw the predominating form, the prism 1 . Obviously its intersectionedges are parallel to the vertical axis, and its basal edges, intersecting $O$, are parallel to $p s$, $t q$ in the projection (f. 820). The planes $i \cdot \bar{i}$, and $i .2$ are now to be added, whose intersections with each other and with $I$ are parallel to $\dot{c}$. The position of one edge, $I / i-\overline{2}$, having been taken, that of the other on the other side is determined by the point where a line parallei te
the axis $\bar{b}$ meets the basal edge of the prism. Similarly the position of the same prismatio edges behind are given by the intersection of lines from front to rear parallel to the axis $\breve{d}$.

The prisms drawn, it remains to add the terminal planes, and as they thus modify one another's position, they are drawn together. The required intersection-lines are easily obtained. The macrodome $1-\bar{\imath}$ is the plane passing through the point $c$ and intersecting the horizontal plane in the line $p a q$; this line is obviously the direction of its intersection-edge with $i-\bar{\imath}$ and with $O$. The prism $i$ - $\overline{2}$ appears (f. 820) as the two lines $m m^{\prime}, n n^{\prime}$; the line $m m^{\prime}$ produced beyond $m$ meets $p a q$ at $z$, this will be one common point for the two planes $1-\bar{\imath}$ and $i-\bar{\eta}$; the second common point is, as always, the point $c$, hence the line joining these two points, transferred to the crystal in the way described. gives the required intersection-edge for $i-2$ and $1-\bar{i}$. Similarly for $i-2$ on the right, the two points of intersection are $c$, and the point where $n^{\prime} n$ and qap, produced, meet, and this gives the second intersection-edge. The planes $1 \cdot \bar{\imath}$ and 1 (right) meet at $d$ and $c$; hence the line $c d$ gives the direction of their in ${ }^{4}$ ersection-edge, whick is also the direction of that of $1-\bar{\imath}$ and 1 (left). and of 1 and $2-\check{2}$, right and lefi on both sides. Still again, the plane 2-2 has the full symbol $2 \dot{2}: \bar{b}: 2 \bar{x}$, or $\dot{c}: \frac{1}{2} \bar{b}: \bar{u}$; and hence intersects the horizontal plane (f. 820) in the lines as (right), at (left), and $a^{\prime} q, a^{\prime} p$ (behind). Hence the intersection-edge of $I, 2-2,1-\check{\imath}$ has the direction of the line joining the points $c$ and $s$ (right), and similarly to the left and behind. The intersection-edge of $2-2$ front, and $2-2$ behind, has the direction of the line joining the points $c$ and $x$ (right) and $c$ and $y$ (left).

The method of obtaining the intersection-edges of the planes will be clear from this example. Practical facility in drawing figures by this or any other

821
 method is only to be obtained by practice.

It will be found that at almost every step there is an opportunity to test the accuracy of the work-thus every point of intersection on the basal plane behind must lie on a line drawn from the corresponding point in front on the basal plane, in the direction of the axis $\breve{a}$; so, too, the point of intersection of 2-2 and 1 (front), 2-2 and $I$ (behind), on one side, must be in the line of the horizontal axis ( $\bar{b}$ ) with that on the other side, and similarly in other cases.

If it were required, as is generally necessary, to coraplete the form ( $f .821$ ) below, it is unnecessary to obtain any new intersection lines, since every line above has its corresponding line opposite and parallel to it below. Moreover, in an orthorhombic crystal every point above has a corresponding point below on a line parallel to the vertical axis. This, as above, will serve as a control of the accuracy of the work.

There is another method of drawing complex crystalline forms which has many advantages and is sometimes to be preferred to any other; it can be explained in a very few words. After the axes have been obtained the diametral prism is constructed upon them. Upon the solid angles of this each plane of the required form is laid off, the edges being taken instead of the

822


823

axes. Suppose that f. 822 represents the diametral prism of an orthorhombic crystal. Here obviously the edge $e=2 \dot{c}, \bar{e}=2 \bar{b}, \check{e}=2 \check{\check{c}}$. The plane $1(\dot{c}: \bar{b}: \breve{u})$ may be laid off on it by taking from the angle $a$ equal portions of the edges $e, \dot{e}, \check{e}$, for instance, conveniently one
half of each, hence the plane appears as mno. Again the plane $2(2 \dot{c}: \bar{b}: \breve{a})$ is laid off by taking the unit lengths of the edges $\bar{e}(\bar{b})$, and $\check{e}(\bar{a})$ and twice the unit length of $e(\dot{c})$, the plane is then $m n b$. Again, the plane $4-\overline{2}(4 \dot{c}: \bar{b}: 2 \grave{l})$ takes the position $n p b$, since $a p=2 \dot{c}, a p=\frac{1}{2} \bar{b}$, and $a n=\ddot{a}$, the ratio of the edges (axes) being the same as in the symbol. So also the plane $2-\overline{2}(2 \dot{c}: 2 \bar{b}: \breve{u})$ has the position $r m o$, since $a o=\dot{c}, a m=\bar{b}$, and $a r=\frac{1}{2} \bar{u}$, here, too, the ratio of the axes being preserved. By plotting the successive planes of the crystal in this way, each solid angle corresponding to an octant, the direction of the intersection-edges for the given form are at once obtained. For example, the intersection-edge for 1 , and the basal plane, as also for 1 and 2 , it is the line $m n$; for 1 and $4-\frac{2}{2}$ it is the dotted line joining the common points $n$ and $a$; for 1 and $2-2$ it is the line $m o$; for 2 and $4-2$, also for 2 and $2-\overline{2}$, it is the line joining the common points $\beta \alpha$.

The direction of the required intersection-edges being obtained in this way, they are used to construct the crystal itself, being transferred to it in the usual way. In f. 823 they have been placed upon the diametral prism, and when this process has been completed for the other angles, and, too, the domes $\bar{e}^{\prime}, e^{\prime \prime}$, are added, the form in f. 824 results.

## On the Drawing of Twin Crystals.

In order to project a compound or twinned crystal it is generally necessary to obtain first the axes of the second individual, or semi-individual, in the position in which they are brought by the revolution of $180^{\circ}$. This is accomplished in the following manner. In f. $825 \mathrm{a} \mathrm{com}-$ pound crystal of staurolite is represented, in which twinning has taken place (1) on an axis normal to $\frac{3}{2}-\check{c}$, and ( 2 ) on an axis normal to $\frac{3}{2}-\frac{3}{2}$. The second, being the more general case, is of the greater importance for the sake of example. In f. $825, c c^{\prime}, b b^{\prime}, a a^{\prime}$ represent the rectangular axes of staurolite ( $\dot{c}=1 \cdot 441, \bar{b}=2 \cdot 112, \breve{a}=1$ ). The twinning-plane $\frac{3}{2}-\frac{3}{2}\left(\frac{3}{2} \dot{c}:-\bar{b}: \frac{3}{2} \bar{a}\right)$

has the position MNR. It is first necessary to construct a normal from the centre $\mathbf{O}$ to this plane. If perpendiculars be drawn from the centre $O$ to the lines MN, NR, MR, they will meet them at the points $x, y, z$, dividing each line into segments proportional to the squares of the adjacent axes;* or $\mathrm{N} x: \mathrm{M} x=\overline{\mathrm{ON}}^{2}: \overline{\mathrm{OM}}^{2}$. In this way the points $x, y, z$ are fixed, and linea

[^59]drawn from any two of them to the opposite angles $\mathrm{R}, \mathrm{N}$, or M will fix the point T . A line joining $T$ and $O$ is normal to the plane ( $\mathrm{MNR}=\frac{3}{2}-\frac{3}{2}$ ). Furthermore, it is obvious that if a revolution of $180^{\circ}$ about TO take place, that every point in the plane MNR will remain equally distant from T . Thus, the point M will take the place $\mu\left(\mathrm{M}^{\prime} \mathrm{T}=\mathrm{T} \mu\right)$, the point $b^{\prime}$ the place $\boldsymbol{\beta}^{\prime}\left(\mathrm{N}^{\prime} \mathrm{T}=\mathrm{T} \boldsymbol{\beta}^{\prime}\right)$, and so on. The lines joining these points $\mu, \boldsymbol{\beta}^{\prime}, x$, and the common centre 0 will be the new axes corresponding to M(), NO, RO. In order


Calcite. to obtain the unit axes corresponding to $\dot{c}, \bar{b}, \check{u}$ it is merely necessary to draw through c a line parallel to $\mathrm{MT}_{\mu}$, meeting $\mu \mathrm{O}$ at $\gamma$, then $\gamma \gamma^{\prime}$ is the new vertical axis corresponding to $c O c^{\prime}$, also $\beta O \beta^{\prime}$ corresponds to $b O b^{\prime}$, and $a \mathrm{O} a^{\prime}$ corresponds to $a \mathrm{O} a^{\prime}$. These three axes then are the azes for the second individual in its twinned position; upon them, in the usual way, the new figure may be constructed and then transferred to its proper position with reference to the normal crystal.

For the second method of twinning, when the axis is normal to $\frac{3}{2}-\check{2}$, the construction is more simple. It is obvious the axis is the line $0 x$, and using this, as before, the new axes are found ; $\kappa \mathrm{O} \kappa^{\prime}$ corresponds to $c \mathrm{O} \mathrm{c}^{\prime}$ (sensibly coinciding with $b b^{\prime}$ ), since $O \wedge \frac{3}{2}-\breve{\imath}=134^{\circ} 21^{\prime}$, and so on.

In many cases the simplest method is. to construct first the normal crystal, then draw through its centre the twinning-plane and the axis of revolution, and determine the angular points of the reversed crystal in the principle alluded to above: that by the revolution every point remains at the same distance from the axis, measured in a plane at right angle to the axis.
Thus in f. 827 when the scalenohedron has been drawn, since the twinning-plane is the basal plane, each angular point, by the revolution of $180^{\circ}$, obtains a position equidistant from this plane and directly below it. In this way each angular point is determined, and the compound crystal is completed in a moment.

## APPENDIX C.

## CATALOGUE OF AMERICAN LOCALITIES OF MINERALS.

The following catalogue * may aid the mineralogical tourist in selecting his routes and arranging the plan of his journeys. Only important localities, which have afforded cabinet specimens, are in general included; and the names of those minerals which have been obtained in good specimens are distinguished by italics, the addition of an exclamation mark (!), or of two (!!), indicates the degree of excellence of the specimens. Many of the localities mentioned have been exhausted, others will now yield good specimens only when further explored with blasting, etc. In general, only those of the localities mentioned can be relied upon as likely to reward the visitor liberally where active work is being continually carried on.

## MAINE.

Al.bany.-Beryl! grcen and black tourmaline, feldspar, rose quartz, rutile. Aroostook.-Red hematite.
AUBURN.-Lepidolite, amblygonite (hebronite), green tourmaline.
Batir.-Vesuvianite, garnet, magnetite, graphite.
Bethel.-Cinnamon garnet, calcite, sphene, beryl, pyroxene, hornblende, epidote, graphite, talc, pyrite, arsenopyrite, magnetite, wad.
Bingham.-Massive pyrite, galenite, blende, andalusite.
Blue Hill Bay. - Arsenical iron, molybdenite! galenite, apatite! fluorite! black tourmaline (Long Cove), black oxide of manganese (Osgood's farm), rhodonite, bog manganese. wolframite.
Bowdorn.-Rose quartz.
Bowdoinuam.-Beryl, molybdenite.
Brunswick.-Green mica, garnet! black tourmaline! molybdenite, epidote, calcite, mus covite, feldspar, beryl.
Buckrield.-Garnet (estates of Waterman and Lowe), iron ore, muscovite! tourmaline.' magnetite.
CAMDAGE FARM - (Near the tide mills), molybdenite, wolframite
CAMDEN.-Macle, galenite, epidote, black tourmaline, pyrite, tale, magnetite.
Carmel (Penobscot Co.).-Stibnite, pyrite, macle.
Corinna. - Pyrite, arsenopyrite.
Deer Isle.-Serpentine, verd-antique, asbestus, diallage, magnetite.
Dexter.-Galenite, pyrite, blende, chalcopyrite, green talc.
Dixfield.-Native copperas, graphite.
East Woodstock.-Muscovite.
Farmington. - (Norton's ledge), pyrite, graphite, bog ore, garnet, staurolite.
Freeport.-Rose quartz, garnet, feldspar, scapolite, graphite, muscovite.
Fryeburg.-Gurnet, beryl.
Georgetown.-(Parker's island), beryl! black tourmaline.
Greenwood.-Graphite, black manganese, beryl! arsenopyrite, cassiterite, mica, rose quartz, garnet, corundum, albite, zircon, molybdenite, magnetite, copperas.

[^60]Hebron.-Cassiterite, arsenopyrite, idocrase, lepidolite, amblygonite (hebron te), rubellite !
indicolite, green tourmaline, mica, beryl, apatite, albite, childrenite, cookeite.
Jewell's Isiand. - Pyrite.
Kataimin Iron Works. - Bog-iron ore, pyrite, magnetite. quartz.
Letter E, Oxford Co.-Staurolite, macle, copperas.
Linnexus.-Hematite, limonite, pyrite, bog-iron ore.
Litcirield.-Sodulite, cancrinite, elsoolite, zircon, spodumene, muscovite, pyrrhotite.
Lubec Lead Mines. - Galenite, chalcopyrite, blende.
Machiasport.-Jasper, epidote, laumontite.
Madawasea Settlements.-Vivianite.
Minot. - Beryl smoky quartz.
Monmouth.-Actinolite, apatite, elcolite, zircon, staurolite, plumose mica, beryl, rutile.
Mт. Abraham.-Andalusite, staurolite.
Nonway.-Chrysoberyl! molybdenite, beryl, rose quartz, orthoclase, cinnamon garnet.
Orr's Island.-Steatite, garnet andalusite.
OxFord. - Gurnet, beryl, apatite, wad, zircon, muscovite, orthoclase.
Pairs.-Green! red! black, and blue tourmaline! mica! lepidolite! feldspar, albite, quarta crystals ! rase quartz, cassiterite, amblygonite, zircon, brookite, beryl, smoky quartz, spodumene, cookcite, leucopyrite.
Parsonsfilld.-Vesurianite! yellow garnet, pargasite, adularia, scapolite, galenite, blende. chalcopyrite.

Perv-Crystallized pyrite.
Phipisburg. - Yellow garnet! manganesian garnet, vesuvianite, pargasite, axinite, laumontite! chabazite, an ore of cerium?
Poland. - Vesuvianite, smoky quartz, cinnamon garnet.
Portland.-Prehnite, actinolite, garnet, epidote, amethyst, calcite.
Pownal.-Black tourmaline, feldspar, scapolite, pyrite, actinolite, apatite, rose quartz.
RAYMOND.-Magnetite, scapolite, pyroxene, lepidolite, tremolite, hornblende, epidote, orihisclase, yellow garnet, pyrite, vesuvianite.
Rockland.-Hematite, tremolite, quartz, wad, talc.
RUMFORD. - Yellow garnet, vesuvianite, pyroxene, apatite, scapolite, graphite.
Rutland.-Allanite.
Sandy River. - Auriferous sand.
Sanford, York Co.-Vesuvianite! albite, calcite, molybdenite, epidote, black tourma'ine, labradorite.

SEARsmont.-Andalusite, tourmaline.
Soutir Berwick. --Macle.
Standisil.--Columbite!
Streaked Mountain.-Beryl! black tourmaline, mica, garnet.
Tromaston. - Calcite, tromolite, hornblende, sphene, arsenical iron (Owl's head), black manganese (Dodge's mountain), thomsonite, talc, blende, pyrite, galenite.

Topsinan.-Quartz, galenite, blende, tungstite? beryl, apatite, molybdenite, columbite.
Union.-Magnetite, bog-iron ore.
Wales.-Axinite in boulder, alum, copperas.
Waterville-Crystallized pyrite.
Windiram (near the bridge).-Staurolite, spodumene, garnet, beryl, amethyst, cyanite, tourmaline.

Winslow.-Cassiterite.
Wintinrop.-Staurolite, pyrite, hornblende, garnet, copperas.
Woodstock.-Graphite, hematite, prehnite, epidote, calcite.
York. - Beryl, vivianite,, oxide of manganeșe.

## NEW HAMPSHIRE.

[^61]Campton.-Beryl!
Canaan.-Gold in pyrites, garnet.
Charleston.--Staurolite macle, andalusite macle, bog-iron ore, prehnite, cyanite.
Cornisir.-Stibnite, tetrahedrite, rutile in quartz! (rare), staurolite.
Croyden.-lolite! chalcopyrite, pyrite, pyrrhotite, blende.
Enfield.-Gold, galenite, staurolite, green quartz.
Franceston.-Soapstone, arsenopyrite, quartz crystals.
Franconia.-Hornblende, staurolite! epidote! zoisite, lematite, magnetite, buack and red manganesian sfrnets, arsenopyrite (danaite), chalcopyrite, molybdenite, prehnite, green quartz, malachite, azurite.
Gilford (Gunstock Mt.).-Magnetic iron ore, native "loadstone."
Gosien.-Greeplite, black tourmaline.
Gilmantown.-Tremolite, epidote, muscovite, tourmaline, limonite, red and yellow quartz crystals.

Grafron.-Mica! (extensively quarried at Glass Hill, 2 m . S. of Orange Summit), albite ! blue, green, and yellow beryls! ( 1 m . S. of 0 . Summit), tourmaline, garruts, triplylite, apatite, fluorite.

Grantham. - Gray staurolite!
Groton.-Arsenopyrite, blue beryl; muscovite crystals.
Hanover.-Garnet, a boulder of quartz containing rutilc! black tourmaline, quartz, cyanite, labradorite, epidote.

Haverimlit.-Głarnet! arsenopyrite, native arsenic, galenite, blende, pyrite, chalcopyrite, magnetite, marcasite, steatite.

Hillsboro' (Campbell's mountain).-Graphite.
Hinsdale.- Rhodonte, black oxide of manganese, molybdenite, indicolite, black tourmaline.

Jackson.-Drusy quartz, tin ore, arsenopyrite, native arsenic, fluorite, apatite, magnetite, moiybdenite, wolframite, chalcopyrite, arsenate of iron.

Jaffrey (Monadnock Mt.).-Cyanite, limonite.
Keene.-Graphite, soapstone, milky quartz, rose quartz.
Is indaff.-Molybdenite, lead and iron ores.
Lebanon.-Bog-iron ore, arsenopyrite, galenite, magnetite, pyrite.
Lisbon.-Staurolite, black and red garnets, granular magnetite, hornblende, epidote, zoisito, hematite. arsenopyrite, galenite, gold, ankerite.

Littleton--Ankerite, gold, bornite, chalcopyrite, malachite, menaccanite, chlorite.
Lyman.-Gold, arsenopyrite, ankerite, dolomite, galenite, pyrite, copper, pyrrhotite.
Lyme.-C'yanite (N. W. part), black tourmaline, rutile, pyrite, chalcopyrite (E. of E. village), stibnite. molybdenite, cassiterite.

MADIson.-Galenite, blende, chalcopyrite, limonite.
Merrimack.-Rutile! (in gneiss nodules in granite vein).
Middletown.-Rutile.
Monadnock Mountain.-Andalusite, hornblende, garnet, graphite, tourmaline, orthoclase.

Moosilauke Mt.-Tourmaline.
Moultonbonough (Red Hill).-Hornbende, bog ore, pyrite, tourmaline.
Newington. -Garnet, tourmaline.
New London.-Beryl, molybdenite, muscovite crystals.
Newport.-Molybdenite.
Orange.-Blue beryla! Orange Summit, chrysoberyl, mica (W. side of mountain), apatite, galenite, limonite.

Orford.-Brown tourmaline (now obtained with difficulty), steatite, rutile, cyanite, brown iron ore, native copper, malachite, galenite, garnet, graphite, molybdenite, pyrrhotite, melacouite, chalcocite, ripidolite.

Pelham.-Steatite.
Piermont.-Micaceous iron, barite, green, white, and brown mica, apatite, titanic iron.
Plymorith.-Columbite, beryl.
Richmond.-Iolite! rutile, steatite, pyrite, anthophyllite, talc.
Rye.-Chiastolite.
Saddleback Mt.-Black tourmaline, garnet, spinel.
Simelburne.-Galenite, black blende, clialcopyrite, pyrite, pyrolusite.
Springrield.-Beryls (very large, eight inches diameter), manganesian garnets! black tourmaline! in mica slate, abbite, mica.
SUlisivan. - ''ourmaline (black), in quartz, beryl.
Surrey.-Amethyst, calcite, galenite, limonite, tourmaline.
Swantey (near Keene). -Magnetic iron (in masses in granite).

Tamwortir (near White Pond).-Galenite.
Unity (estate of James Neal).-Copper and iron pyrites, chlorophyllite, green mica, radib ated actinolite, garnet, titaniferous iron ore, magnetite, tourmaline.

Walpole (near Bellows Falls).-Macle, staurolite, mica, graphite.
Ware.-Graphite.
Warren.-Chalcopyrite, blende, epidote, quartz, pyrite, tremolite, galenite, rutile, talo, molybdenite, cinnamon stone! pyroxene, hornblende, beryl, cyanite, tourmaline (massive).

Waterville.-Labradorite, chrysolite.
Westmoreland (south part). -Molybdenite! apatite! blue feldspar, bog manganese (north village), quartz, fluorite, chalcopyrite, oxide of molybdenum and uranium.

White Mrs. (Notch near the "Crawford House"). -Green octahedral fluorive, quartz crystals, black tourmaline, chiastolite, beryl, calcite, amethyst, amazonstone.

Wilmot. - Beryl.
Winchester. - Pyrolusite, rhodochrosite, psilomelane, magnetite, granular quartz, spodu. mene.

## VERMONT.

ADDIson.-Iron sand, pyrite.
ALBURGI.-Quartz crystals on calcite, pyrite.
ATHENS.-Steatite, rhomb spar, actinolite, garnet.
Baltimore.-Serpentine, pyrite!
Barnet.-Graphite.
Belvidere. - Steatite, chlorite.
Bennington.-Pyrolusite, brown iron ore, pipe clay, yellow ochre.
Berksulre.-Epidote, hematite, magnetite.
Bethel.-Actinolite! talc, chlorite, octahedral iron, rutile, brown spar in steatite.
Brandon.-Braunite, pyrolusite, psilomelane, limonite, lignite, white clay, statrary marble; fossil fruits in the lignite, graphite, chalcopyrite.
Brattleborough.-Black tourmaline in quartz, mica, zoisite, rutile, actinolite, scapolite, spodumene, roofing slate.
Bridgewater.-Talc, dolomite, magnetite, steatite, chlorite, gold, native copper, blende, galenite, blue spinel, chalcopyrite.
Bristol.-Rutile, limonite, manganese ores, magnetite.
Brookfield. - Arsenopyrite, pyrite.
Савот.-Garnet, staurolite, hornblende, albite.
Castleton.-Roofing slate, jasper, manganese ores, chlorite.
Cavendish.-Garnet, serpentine, tale, steatite, tourmaline, asbestus, tremolite.
Chester.--Asbestus, feldspar, chlorite, quartz.
Chittenden.-Psilomelane, pyrolusite, brown iron ore, hematite and magnetite, galenite, iolite.

Colchester.-Brown iron ore, iron sand, jasper, alum.
Corintri.-Chalcopyrite (has been mined), pyrrhotite, pyrite, rutile, quartz.
Coventry.-Rhodonite.
Craftsbury.-Mica in concentric balls, calcite, rutile.
Derby. - Mica (edamsite).
Dummerston.-Rutile, roofing slate.
Fair Ilaven. - Roofing slate, pyrite.
Fletcher. - Pyrite, magnetite, acicular tourmaline.
Grafron.-The steatite quarry referred to Grafton is properly in Athens; quartz, actinolite.
Goilford.-Scapolite, rutile, roofing slate.
Hartaord.-Calcite, pyrite! cyanite in mica slate, quartz, tourmaline.
Irasburgh.-Rhodonite, psilomelane.
Jay. - Chromic iron, serpentine, amianthus, dolomite.
Lowell.-Picrosmine, amianthus, serpentine, cerolite, talc, chlorite.
Marlboro'.-Rhomb spar, steatite, garnet, magnetite, chlorite.
Mendon.-Magnetic iron ore.
Middlebury.-Zircon.
Micdlesex.-Rutile! (exhausted).
Monkton. - Pyrolusite, brown iron ore, pipe clay, feldspar.
Moretown.-Smoky quartz! steatite, tale, wad, rutile, serpentine.
Morristown.-Galenite.
Mount Holly.-Asbestus, chlorite.
New Fane. -Glassy and asbestiform actinolite, steatite, green quartz (called chrysopra3e
at the locality), chalcedony, drusy quartz, garnet, chromic and titanic iron, rhomb spar, serpentine, rutile.

Norwicir. - Actinolite, feldspar, brown spar in talc, cyanite, zoisite, chalcopyrite, pyrite
Pittsfond.-Brown iron ore, manganese ores.
Plymoutir.-Siderite, magnetite, hematite, gold, galenite.
Pi.ympton.-Massive hornblende.
Putney.-Fluorite, brown iron ore, rutile, and zoisite, in boulders, staurolite.
Reading.-Glassy actinolite in tale.
Readsboro'.-Gilassy actinolite, steatite, hematite.
Ripton.-Brown iron ore, augite in boulders, octahedral pyrite.
Rociester.- Rutile, hematite cryst., magnetite in chlorite slate.
Rockingham (Bellows Falls).-Cyanite, indicolite, feldspar, tourmaline, fluorite, carcite, ןrehnite, staurolite.

Roxbury.-Dolomite, talc, serpentine, asbestus, quartz.
Rutland.-Magnesite, white marble, hematite, serpentine, pipe clay.
Salisbury. - Brown iron ore.
Siaron.-Quartz crystals, cyanite.
Shoreinam.-Pyrite, black marble, calcite.
Sifrewsibury. - Magnetite and chalcopyrite.
Starksboro'.-Brown iron ore.
Stirling.-Chalcopyrite, talc, serpeutine.
Stockbridge - Arsenopyrite, magnetite.
Strafford.-Magnetite and chulcopyrite (has been worked), native copper, hornblende, copperas.
Thetford.-Blende, galenite, cyanite, chrysolite in basalt, pyrrhotite, feldspar, ronfing slate, steatite, garnet.

Townsilend.-Actinolite, black mica, talc, steatite, feldspar.
Troy.-Magnetite, tale, serpentine, picrosmine, amianthus, steatite, one mile southeast of village of South Troy, on the farm of Mr. Pierce, east side of Missisco, chromite, zaratite.
Vershire.-Pyrite, chalcopyrite, tourmaline, arsenopyrite, quartz.
Wardsboro'. - Zoisite, tourmaline, tremolite, hematite.
Warren.-Actinolite, magnetite, wad, serpentine.
Waterbury.-Arsenopyrite, chalcopyrite, rutile, quartz, serpentine.
Waterville.-Steatite, actinolite, talc.
Weatherșfield. -Steatite, hematite, pyrite, tremolite.
Wells' River.-Graphite.
Westrield.-Steatite, chromite, serpentine.
Westminster.-Zoisite in boulders.
Windham.-Glassy actinolite, steatite, garnet, serpentine.
Woodbury.-Massive pyrite.
Woodstock. -Quartz crystals, garnet, zoisite.

## MASSACHUSETTS.

Alford.-Galenite, pyrite.
ATHoL.-Allanite, fibrolite (?), epidote! babingtonite?
auburn.-Masonite.
Barre.-Rutile! mica, pyrite, beryl, feldspar, garnet.
Great Barrington.-Tremolite.
Bedrord.-Garnet.
Belcherton.-Allanite.
Bernardston.-Magnetite.
Beverly. - Columbite, green feldspar, cassiterite.
Blanford.-Serpentine, anthophyllite, actinolite! chromite, cyanite, rose quartz in boulders.

Bolton.-Scapolite! petalite, sphene, pyroxene, nuttalite, diopside, boltonite, apatite, magnesite, rhomb spar, allanite, yttrocerite! cerium ochre? (on the scapolite), spmel.

Boxborovari.-Scapolite, spinel, garnet, augite, actinolite, apatite.
Briahton.-Asbestus.
Brimpield (road leading to Warren).-lolite, adularia, molybdenite, mica, garnet.
Carlisle.-Tourmaline, garnet! scapolite, actinolite.
Cuarlestown. - Prehnite, laumontite, stilbite, chabazite, quartz crystals, melanolite.
Chelarsford.-Scapolite (chelmsfordite), chondrodite, blud spinel, aminn:hus/ rowe quartz.

Chester.-Hornblende, scapolite, zoisite, spodumene, indicolite, apatite, magnetite, chromite, stilbite, heulandite, analcite and chabazite. At the Emery Mine, Chester Factories.Corundum, margarite, diaspore, epidote, corundophilite, chloritoid, tourmaline, menaccan. ite ! rutile, biotite, indianite? andesite? cyanite, amesite.

Ciesterfieid.-Blue, green, and red tourmaline, cleavelardite (albite), lepidolite, smoky quartz, microlite, spodumene, cyanite, apatite, rose beryl, garnet, quartz crystals, stancrolite, cassiterite, columbite, zoisite, uranite, brookite (eumanite), scheelite, anthophyllite, bornite.

Conway.-Pyrolusite, fluorite, zoisite, rutile !! native alum, galenite.
Cummington.-Rhodonite! cummingtonite (hornblende), marcasite, garnet.
Dedifam.-Asbestus, galenite.
Deerfierd.-Chabazite, heulandite, stilbite, amethyst, carnelian, chalcedony, agute.
Fitciburg (Pearl Hill).-Beryl, staurolite! garnets, molybdenite.
Foxborovgh.-Pyrite, anthracite.
Franklin.-Amethyst.
Gositen.-Mica, albite, spodumene! blue and green tourmaline, beryl, zoisite, smoky quarts, colnmbite, tin ore, galenite, beryl (goshenite), piblite (cymatolite).

Greenfield (in sandstone quarry, half mile east of village).-Allophane, white and greenish.

Hatfield.-Barite, yellow quartz crystals, galenite, blende, chalcopyrite.
Hawley.-Micaceous iron, massive pyrite, magnetite, zoisite.
Heati.-Pyrite, zoisite.
Hinsdale. - Brown iron ore, apatite, zoisite.
Hubbardston.-Massive pyrite.
Lancaster.-Cyanite, chiastolite! apatite, staurolite, pinite, andalusite.
Lee.-T'remolite! sphene! (east part).
Lenox.-Brown hematite, gibbsite (?)
Leverett.-Barite, galenite, blende, chalcopyrite.
Leyden.-Zoisite, rutile.
Littrefieid. - Spinel, scapolite, apatite.
Lynnfieid.-Magnesite on serpentine.
Martha's Vineyard. - Brown iron ore, amber, selenite, radiated pyrite.
Mendon.-Mica! chlorite.
Middlefield.-Glassy actinolite, rhomb spar, steatite, serpentine, feldspar, drusy quartz apatite, zoisite, nacrite, chalcedony, talc! deweylite.

Milbury. - Vermiculite.
Montague.-Hematite.
Newbury.-Serpentine, chrysotile, epidote, massive garnet, siderite.
Newburyport.-Serpentine, nemalite, uranite.-Argentiferous galenite, tetrahedrite, chalcopyrite, pyrargyrite, etc.

Neiv Braintree.-Black lourmaline.
NorwICH.-Apatite! black tourmaline, beryi, spodumene! triphylite (altered), blende, quartz crystals, cassiterite.

Northfield.-Columbite, fibrolite, cyanite.
Palmer (Three Rivers).-Feldspar, prehnite, calc spar.
Pelifam. - Ashestus, serpentine, quartz crystals, beryl, molybdenite, green hornstone, epidote, amethvst, corundum, vermiculite (pelhamite).

Plainfield. - Cummingtonite, pyrolusite, rhodonite.
Ricimond.-Brown iron ore, gibbsite! allophane.
RockPort.-Danalite, cryophyllite, annite, cyrtolite (altered zircon), green and white ortho. clase.

Rowe.-Epidote, talc.
Soutir Royalston.-Beryl!! (now obtained with great difficulty), mica!! feldspar ! allanitc. Four miles beyond old loc., on farm of Solomon Heywood, mica ! beryl! jeldspar ! menaccanite.

RUSSEL - Schiller spar (diallage ?), mica, serpentine, beryl, galenite, chalcopyrite.
Salem.-In a boulder, cancrinite, sodalite, elæolite.
Saugus. - Porphyry, jasper.
Sifeffield.-Asbestus, pyrite, native alum, pyrolusite, rutile.
Shelburne. - Ratile.
Shutesbury (east of Locke's Pond).-Molybdenite.
SOJTIIAMPTON.-Galenite, cerussite, anglesite, wulfenite, fluorite, barite, pyrite, chalcopyrite, blende, corneous lead, pyromorphite, stolzite, chrysocolla.

STERLING.-Spodumene, chiastolite, siderite, arsenopyrite, blende, galenite, chalcopyrite pyrite, sterlingite (damourite).

Stoneham. -Nephrite.

Eturbripae.-Graphite, garnet, apatite, bog ore.
Swampscot.-Orthite, feldspar.
TAUNTON (one mile south).-Paracolumbite (titanic iron).
Turner's Falls (Conn. River).-Chalcopyrite, prehnite, chlorite, chloror haite, siderite tnalachite, magnetic iron sand, anthracite.

Tyringiram. - Pyroxene, scapolite.
Uxbridge.-Galenite.
Wanwick.-Massive garnet, radiated black tourmaline, magnetite, beryl, epidote.
Wasimenton.-Graphite.
Westrield.-Schiller spar (diallage), serpentine, steatite, cyanite, scapolite, actinolite.
Westrord-Andalusite!
West Hampton.-Galenite, argentine, pseudomorphous quartz.
West Springaielid.-Prehnite, ankerite, satin spar, celestite, bituminous coal.
West Stockbridge - Hematite, fibrous pyrolusite, siderite.
Whately.-Native corper, galenite.
Willifamsburg. - Zoisite, pseudomorphous quartz, apatite, rose and smoky quartz, galezite pyrolusite, chalcopyrite.

Whlidamstown.-Cryst. quartz.
Windson.-Zoisite, actinolite, rutile!
WORCESTER.-Arsenopyrite, idocrase, pyroxene, garnet, amianthus, bucholzite, siderite, galenite.

Wortiington.-Cyanite.
Zoar.-Bitter spar, talc.

## RHODE ISLAND.

Bristol. -Amethyst.
Coventry.-Mica, tourmaline.
Cranston. - Actinolite in talc, graphite, cyanite, mica, melanterite, bog iron.
Cumberland.-Manganese, epidote, actinolite, garnet, titaniferous iron, magnetite, red hematite, chalcopyrite, bornite, malachite, azurite, calcite, apatite, feldspar, zoisite, mica, quartz crystals, ilvaite.

Diamond Hill.-Quartz crystals, hematite.
Foster.-Cyanite, hematite.
Gloucester.-Magnetite in chlorite slate, feldspar.
Joinsston.-Talc, brown spar, calcite, garnet, epidote, pyrite, hematite, magnetite, chalcopyrite, malachite, azurite.

Lime Rock.-Calcite crystals, quartz pyrite.
Lincoln.-Calcite dolomite.
Natic.-See Warwick.
Newport.-Serpentine, quartz crystals.
Portsmouth.-Anthracite, graphite, asbestus, pyrite, chalcopyrite.
Smitirfield.-Dolomite, calcite, bitter spar, siderite, nacrite, serpentine (bowenite), tremnlite, asbestus, quartz, magnetic iron in chlorite slate, talc! octahedrite, feldspar, beryl.

Valley Falls.-Graphite, pyrite, hematite.
Warwick (Natic village).-Masonite, garnet, graphite, bog iron ore.
Westerly.-Menaccanite.
Woonsocket.-Cyanite.

## CONNECTICUT.

Berlin.-Barite, datolite, blende, quartz crystals.
Bolton.-Staurolite, chaloopyrite.
Bradleyville (Litchfield).-Laumontite.
BristoL.-Chalcocite! chatcopyrite, barite, bornite, talc, allophane, pyromorphite, calcite, malachite, galenite, quartz.
Brookfield.-Galenite, calamine, blende, spodumene, pyrrhotite.
Canaln.-T'remolite and white augite! in dolomite, canaanite (massive pyroxene).
Chatham.-Arsenopyrite, smaltite, chloanthite (ehathamite), scorodite, niccolite, beryl, erythrite.

CaEsirire.-Barite, chalcocite, bornite cryst., malachite, kaolin, natrclite, prehnite, chabs vite, datolite.
Chester.-Sillimanite! zircon, epidote.

Cornwall. - Graphite, pyroxene, actinolite, sphene, scapolite.
Danbury.-Danburite, oligoclase, moonstone, brown tourmaline, orthoclase, pyroxene parathorite.

Farmington.-Prehnite, chabrzite, agate, native copper; in trap, diabantite.
Granbx.-Green malachite.
Greenwiou.-Black tourmaline.
Haddam.-Chrysoberyl! beryl! epidote! tourmaline! feldspar, zarnet! iolite! olighiase. chlorophyllite! automolite, magnetite, adularia, apatite, columbite! (hermannolite), zircon (calyptolite), mica, pyrite, marcasite, molybdenite, allanite, bismuth, bismuth ochre, bismutite.

Hadlyme. - Chabazite and stilbite in gneiss, with epidote and garnet.
Hartford. - Datolite (Rocky Hill quarry).
Kent.-Brown iron ore, pyrolusite, ochrey iron ore.
Litchfield.-Cyanite with corundum, apatite, and andalusite, menaccanite (washington• ite), chalcopyrite, diaspore, niccoliferous pyrrhotite, margarodite.

Lyme.-Garnet, sunstone.
Meriden.-Datolite.
Midnlefield Falls. - Datolite, chlorite, etc., in amygdaloid.
Middletown.-Mica, lepidolite, with green and red tourmaline, albite, feldspar, columbito ! prehnite, garnet (sometimes octahedral), beryl, topaz, uranite, apatite, pitchblende; at lead mine, galenite, chalcopyrite, blende, quartz, calcite, fluorite, pyrite, sometimes capillary.

Milford.-Sahlite, pyroxene, asbestus, zoisite, verd-antique, marble, pyrite.
New Haven.-Serpentine, asbestus, chromic iron, sahlite, stilbite, prehnite, chabazite, gmelinite, apophyllite, topazalite.

Newtown.-Cyanite, diaspore, rutile, damourite, cinnabar.
NoRwICI.-Sillimanite, monazite! zircon, iolite, corundum, feldspar.
OxFORD, near Humphreysville.-Cyanite, chalcopyrite.
Plymoutir.-Galenite, heulandite, fluorite, chlorophyllite! garnet.
Reading (near the line of Danbury).-Pyroxene, gainet.
Roaring Brook (Cheshire).-Datolite! calcite, prehnite, saponite.
Roxbury.-Siderite, blende, pyrite!! galenite, quartz, chalcopyrite, arsenopyrite, limon. te.
Salisbury.-Broon iron ore, ochrey iron, pyrolusite, triplite, turgite.
Saybrook.-Molybdenite, stilbite, plumbago.
Seymour.-Native bismuth, arsenopyrite, pyrite.
Simsburx.-Copper glance, green malachite.
Southbury. -Rose quartz, lanmontite, prehnite, calcite, barite.
Southington.--Barite, datolite, asteriated quartz crystals.
Stafford-Massive pyrites, alum, copperas.
Stonington.-Stilbite and chabazite on gneiss.
Tariffrille.-Datoite.
Thatcuersville (near Bridgeport).-Stilbite on gneiss, babingtonite?
Tolland.-Staurolite, massive pyrites.
Trumbull and Monroe.-Chlorophane, topaz, beryl, diaspore, pyrrhotite, pyrite, niccolite, scheelite, woolframite (pseudomorph of scheelite), rutile, native bismuth, tungstic acid, siderite, mispickel, argentiferous galenite, blende, scapolite, tourmaline, garnet, albite,
augite, graphic tellurium (?), margarodite.
WASHINGTON.-Triplite, menaccanite! (washingtonite of Shepard), rhodochrosite, natrolite, andalusite (New Preston), cyanite.

Watertown, near the Naugatuck.-White sahlite, monazite.
West Farms.-Asbestus.
Willimantic.-Topaz, monazite, ripidolite.
Winchester and Wilton.-Asbestus, garnet.

## NEW YORK.

ALBANY CO.-BETHLEHEM.-Calcite, stalactite, stalagmite, calcareous sinter, snows gypsum.

Coeyman's Landing.-Gypsum, epsom salt, quartz crystals at Crystal Hill, three milea south of Albany.

Guildfrland.-Petroleum, anthracite, and calcite, on the banks of the Norman's Kill two miles south of Albany.

Watervliet.-Quarte crystals, yellow drusy quarta.
aLLEGHANY CO.-Cuba.-Calcareous tuta, petroleum, $3 \frac{1}{2}$ miles from the village.
Cattaraugus CO.-Freedom.-Petroleum.
CAYUGA CO.-AUBURN.-Celestite, calcite, fluor spar, epsomite.
Cayuga Lake.-sulphur.
LUDLowville.-EEsomite.
Union Sphings.-Selenite, gypsum.
Springrort.-At Thompson's plaster beds, sulphur! selenite.
Si'Ring ville.--Nitroger springs.
CLinton Co.-Arnold Iron Mine.-Magnetite, epidote, molybdenite.
Fincir Ore Bed.-Calcite, green and purple fluor.
CHATAUQUE CO.-Fredonia.-Petroleum, carburetted hydrogen.
Ladna. - Petroleum.
Sheridan.-Alum.
COLUMBIA CO.-Austerlitz.-Earthy manganese, wulfenite, chalcocite; Livingstor lead mine, vitreous silver?
Cifatiam.-Quartz, pyrite in cubic crystals in slate (Hillsdale).
Canann.-Chalcocite, chalcopyrite.
Hudson.-Epidote, selenite!
New Lebanon.-Nitrogen springs, graphite, anthracite ; at the Ancram lead mine, galenite, barite, blende, wuifenite (rare), chalcopyrite, calcareous tufa; near the city of Hudson, epsom salt, brown spar, wad.

DUTCHESS CO.-Amenia.-Dolomite, limonite, turgite.
Beckian.-Dolomite.
Dover.-Dolomite, tremolite, garnet (Foss ore bed), staurolite. limonite.
Fismikil.-Dolomite; near Peckville, talc, asbestus, graphite, hornblende, augite, actinolite, hydrous anthophyllite, limonite.

Nortri Eastr.-Chalcocite, chalcopyrite, galenite, blende.
Pawling.-Dolomite.
Rhinebecir.-Calcite, green feldspar, epidote, tourmaline.
Union Vale.-At the Clove mine, gibbsite, limonite.
ESSEX CO.-Alexandria.-Kirby's graphite mine, graphite, pyroxene, scapolite, sphene.
Crown Point.-Apatite (eupyrchroite of Emmons), brown tourmaline! in the apatite, chlorite, quartz crystals, pink and blue calcite, pyrite; a short distance south of J. C. Hammond's house, garnet, scapclite, chalcopyrite, aventurine feldspar, zircon, mageetis iron (Peru), epidote, mica.

Kerne.-Scapolite.
Lewis.-Tabular spar, colophonite, garnet, labradorite, hornblende, actinolite; ten miles south of the village of Keeseville, mispickel.

Long Pond.-Apatite, garnet, pyroxene, idocrase, coccolite!! scapolite, magnetite, blue calcite.

McIntyre. - Labradorite, garnet, magnetite.
Morlail, at Saadford ()re Bed.-Magnetite, apatite, allanite! lanthanite, actinolite, and feldspar ; at Fisher Ore Bed, magnetic iron, feldspar, quartz; at Hall Ore Bed, or "New Ore Bed," magnetite, zircons; on Mill brook, calcite. pyroxene, hornblende, albite; in the town of Moriah, magnetite, black mica ; Barton Hill Ore Bed, albite.
Newcomb.--Labradorite, feldspar, magnetite, hypersthene.
Port henry. - Brown tourmaline, mica, rose quartz, serpentine, green and black pyroxene, hornblende, cryst.pyrite, graphite, wollastonite, pyrrhotite, adularia; phlogopite! at Cheever Ore Bed, with magnetite and serpentine.

Roger's Rock. - Graphite, wollastonite, garnet, colophonite, feldspar', adularia, pyroxene, sphene, soccolite.

Schrnon.-C'alcite, pyroxene, chondrodite.
T'iconderoga.-Graphite! pyroxene, sahlite, sphene, black tourmaline, cacoxene? (Mt Defiance).

Westrort.-Labradorite, prehnite, magnetite.
Willsboro'-Wo.lastonite, colophonite, garnet, green coccolite, hornblende.

FRANKLIN CO.- Chateaugay.-Nitrogen springs, calcareous tufas.
Malone.--Massive pyrite, magnetite.
GENESEE CO.-Acid springs containing sulphuric acid.
GREENE CO.-Catskill.-Calcite.
Diamond Hill.-Quartz crystals.
HERKIMER CO.-Fairfielid.--Quartz crystals, fetid barite.
Littre Falls.-Quartz crystals/ barite, calcite, anthracite, pearl spar, smoky quarta, one mile south of Little Falls, calcite, brown spar, feldspar.

Middlevil! e, -Quartz crystals! salcite, brown and pearl spar, anthracite.
Newport.-Quartz crystals.
Salisbury.-Quartz crystals! blende, galenite, pyrite, chalcopyrite.
Staik.-Fibrous celestite, gypsum.
HAMILTON CO.-Long Lake.-Blue calcite.
JEFT'ERSON CO.-ADAMS.-Fluor, calc tufa, barite.
AIffandira.-On the S.E. bank of Muscolonge Lake, fluorite, phlogopite, chalcopyrite, apatice; on IIigh Island, in the St. Lawrence River, feldspar, tourmaline, hornblende, orthoclase, celestite.

ANTWERP.-Stirling iron mine, hematite, chalcodite, siderite, millerite, red hematite, crys tallized quartz, yellow aragonite, niccoliferons pyrite, quartz crystals, pyrite; at Oxbow, calcite! porous coralloidal heavy spar; near Vrooman's lake, calcite! vesuvianite, phiogopite! pyroxene, sphene, fluorite, pyrite, chalcopyrite ; also feldspar, bog-ivon ore, scapolite (farm of David Eggleson), serpentine, tourmaline (yellow, rare).

Brownsvilie.-Celestite in slender crystals, calcite (four miles from Watertown).
Natural Bimde.-Feldspar, gieseckite! stentite pseudomorphous after pyroxene, apatite.
New Connecticut--Sphene, brown phlogopite.
Omar.-Beryl, feldspar, hematite.
Piilladelpiila. - Garnets on Indian river, in the village.
Pamelia.-Agaric mineral, calc tufa.
Pierrepont.-Tourmaline, sphene, scapolite, hornblende.
Pillar Point.-Massive barite (exhausted).
Tieresa. - F'luorite, calcite, hematite, hornblende, quartz crystals, serpentine (associated with hematite), celestite, strontianite; the Muscolonge Lake locality of fluor is exhausted.

Watertown.-Tremolite, agaric mineral, calc tufa, celestite.
Wilna.-One mile north of Natural Bridge, calcite.
LEWIS CO.-DIANA (localities mostly near junction of crystalline and sedimentary rocks, and within two miles of Natural Bridge).-Scapolite! wollastonite, green coccolite, feldspar, tremolite, pyroxene! sphene.! ! mica, quartz crystals, drusy quartz, cryst. pyrite, pyrrhotite, blue calcite, serpentine, rensselaerite, zircon, graphite, chlorite, hematite, bog-iron ore, irou sand, apatite.

Greig.-Magnetite, pyrite.
Lowville.-Caicite, fluorite, pyrite, galenito, blende, calc tufa.
Martinsiburgh.-Wad, galenite, etc., but mine not now opened, calcite.
Watson, Bremen.-Bog-iron ore.
MONROE CO.-Rochester.-Pearl spar, calcite, snowy gypsum, fluor, celestite, galenite, blende, barite, hornstone.

MONTGOMERY CO.-CANAJomarie. - Anthracite.
Palatine.-Quartz crystals, drusy quartz, anthracite, hornstone, agate, garnet.
Root.-Drusy quartz, blende, barite, stalactite, stalagmite, galenite: pyrite.
NEW YORK CO.-Corlear's Hook.-Apatite, brown and yellow feldspar, sphene.
Kingsbridge.-Tremolite, pyroxene, mica, tourmaline, pyrites, rutile, dolomite.
Harlem.-Epidote, apophyllite, stilbite, tourmaline, vivianite, lamellar feldspar, mica.
New York.-Serpentine, amianthus, actinolite, pyroxene, hydrous anthophyllite, garnet, staurolite, molybdenite, graphite, chlorite, jasper, necronite, feldspar. In the excavations for the 4th Avenue tunnel, 1875, harmotome, stilbite, chabazite, heulandite, etc.

NiAgara CO. - Lewiston.--Epsomite.
Lockport.-Celestite, calcite, selenite, anhydrite, fluorite, dolomite, blende.
Niagara Falls.--Calcite, fluorite, blende, dolomite.
ONEIDA CO.-Boonville.-Calcite, woollastonite, coccolite.
Clinton.-Blende, lenticularr argillaccous iron ore; in rocks of the Clinton Group, stronti anite, celestite, the former covering the latter.

ONONDAGA CO.-Camillus.-Selerite and fibrous gypsum.
Cold Spring.-Axinite.
Manlius.-Gypsum and fluor.
Syracuse.-Serpentine, celestite, selenite, barite.
ORANGE CO.-CORNVALL.-Zircon, chondrodite, hornblende, spinel, massive feldspar, fibrous epidote, hudsonite, menaccanite, serpentine, coccolite.

Deer Park.-Cryst. pyrite, galenite.
Monroe.-Mica! sphene! garnet, colophonite, epidote, chondrodite, allanite, bucholzite, brown spar, spinel, hornblende, talc, menaccanite, pyirhotite, pyrite, chromite, graphite, rastolyte, moronolite.

At Wilks and O'Neil Mine in Monroe.-Aragonite, magnetite, dimagnetite (pseud. ?), jenkinsite, asbestus, serpentine, mica, hortonolite.

At Two Ponds in Monroe.-Pyroxene! chondrodite, hornblende, scapolite! zircon, sphene, apatite.

At Greenwood Furnace in Monroe.-Chondrodite, pyroxene! mica, horntlende, spinel, scapolite, biotite! menaccanite.
At Forest of Dean.-lyyoxene, spinel, zircon, scapolite, hornblende.
Town of Warwick, Warwick Vildage.-Spinel! zircon, serpentine! brown spar, pyroxene! hornblende! pseudomorphous steatite, feldspar! (Rock Hill), menaccanite, clintonite, tourmaline (R. H.), rutile, sphene, molybdenite, arsenopyrite, marcasite, pyrite, yellow iron sinter, quartz, jasper, mica, coccolite.
Amity.-Spinel! garnet, scapolite, hornblende, vesuvianite, epidote! clintonite! magnetite, tourmuline, warwickite, apatite, chondrodite, talc! pyroxene! rutile, menaccanite, zircon, corundum, feldspar, sphene. calcite, serpentine, schiller spar (?), silvery mica.
Eoenville.-Apatite, chondrodite! hair-brown hornblende! tremolite, spinel, tourmaline, warwickite, pyroxene, sphene, mica, feldspar, mispickel, orpiment, rutile, menaccanite, scorodite, chalcopyrite, leucopyrite (or löllingite), allanite.

West Point.-Feldspar, mica, scapolite, sphene, hornblende, allanite.
PUTNAM CO.-Brewster, Tilly Foster Iron Mine.-Chondrodite! (also humite and clinohumite) crystals very rare, magnetite, dolomite, serpentine pseudomorphs, brucite, enstatite, ripidolite, biotite, actinolite, apatite, pyrrhotite, fluorite, albite, epidote, sphene.
Carmel (Brown's quarry).-Anthophyllite, schiller spar (?), orpiment, arsenopyrite, epidote.
Cold Spring.-Chabazite, inica, sphene, epidote.
Patterson.-Whit pyroxene! calcite, asbestus, tremolite, dolomite, massive pyrite.
Pirillifstown.-Tremolite, cmianthus, serpentine, sphene, diopside, green coccoïte, horn blende, scapolite, stilbite, mica, laumontite, gurhofite, calcite, magnetite, chromite.
Phillips Ore Bed.-Hyalite, actinolite, massive pyrite.
RENSSELAER CO.-Hoosic.-Nitrogen springs.
Langingburgin.-Epsomite, quartz crystals, pyrite.
Trov.-Quartz crystals, pyrite, selenite.
RICHMOND CO.-ROssville.-Lignite, cryst. pyrite.
Quarantine.-Asbestus, amianthus, aragonite, dolomite, gurhofite, brucite, serfontine tillc, magnesite.

ROCKLAND CO.-Caldwell.-Calcite.
Girassy Pornt. - Serpentine, actinolite.
Haverstraw. - Hornblende, barite.
Ladentown.-Zircon, malachite, cuprite.
Prermont.-Datolite, stilbite, apophyllite, stellite, prehnite, thomsonite, caloite, chabazite
Stony Pornt.-Cerolite, lamellar hornblende, asbestus.

ST. LAWRENCE CO.-CANTON.-Massive pyrite, calcite, brown tourmaline, sphene, serpentine, taic, rensselaerite, pyroxene, hematite, chalcopyrite.

Dekalb.-Hornblende, barite, fluorite, tremolite, tourmaline, blende, graphite, pyroxene, quartz (spongy), serpentine.

Edwards.-Brown und silvery mica! scapolite, apatite, quartz crystals, actinolite, trerolite! hematite, serpentine, magnetite.

Fine.-Black mica, hornblende.
Fowler.-Barite, quartz crystals! hematite, blende, galenite, tremolite, chalcedony, bog ore, satin spar (assoc. with serpentine), pyrite, chalcopyrite, actinolite, rensselaerite (uear Somerville).

Gouverneur.-Calcite! serpentine! hornllende! scapolite! orthoclase, tourmaline! idoorase (one mile sonth of G.), pyroxene, malacolite, apatite, rensselaerite, serpentine, sphene, fluorite, barite (farm of Judge Dodge), black mica, phlogopite, tremolite! asbestus, hematite, graphite, vesuvianite (near Somerville in serpentine), spinel, houghite, scapolite, phlogopite, dolomite ; three-quarters of a mile west of Somerville, chondrodite, spinel ; two miles north of Somerville, apatite, pyrite, broun tourmaline!!

Hammond.-Apatite! zircon! (farm of Mr. Hardy), orthoclase (loxocase), pargasite, barite, pyrite, purple fluorite, dolomite.

Hermon-Quartz crystals, hematite, siderite, pargasite, pyroxene, serpentine, tourmaline, bog-iron ore.

Macomb.-Blende, mica, galenite (on land of James Averil), sphene.
Mineral Point, Morristown.-Fluorite, blende, galenite, phlogopite (Pope's Mills), barite Ogdensburg.-Labradorite.
Pitcairn.-Satin spar, associated with serpentine.
Potsdam.-Hornblende! -eight miles from Potsdam, on road to Pierrepont, feldspar, tourmaline, black mica, hornblende.

Rossie (Iron Mines).-Burite, hematite, coralloidal aragonite in mines near Somerville, limonite, quartz (sometimes stalactitic at Parish iron mine), pyrite, pearl spar.

Rossie Lead Mine.-Crlcite! galenite! pyrite, celestite, chalcopyrite, hematite, cerussite, anglesite, octahedral fuor, black phlogopite.

Elsewhere in Rossic. - Calcite, harite, quartz crystals, chondrodite (near Yellow Lake), feldspar! pargasite! apatite, pyroxene, hornblende, sphene, zircon, mica, fluorite, serpentine, automolite, pearl spar, graphite.

Russel.-Pargasite, specular iron, quartz (dodec.), calcite, serpentine, rensselacrite, magnetite.

SARATOGA CO.-Greenfield.-Chrysoberyl! garnet! tourmaline! mica, feldspar, apatite, graphite, aragonite (in iron mines).

SCHOHARIE CO.-Ball's Cave, and others.-Calcite, stalactites.
Carlisle.-Fibrous barite, cryst. and fib. calcite.
Middlebury.-Anthracite, calcite.
Siraron.-Calcareous tufa.
Schomarie.-Fibrous celestite, strontianite! cryst. pyrite!
SENECA CO.-CANOGA.-Nitrogen springs.
SULLIVAN CO.-Wurtzboro'.-Galenite, blende, pyrite, chalcopyrite.
TOMPKINS CO -Ithaca.-Calcareous tufa.
ULSTER CO.-Ellenville.-Galenite, blende, chalcopyrite! quartz, brookite.
Marbletown.-Pyrite.
Warren Co.-Caldwell.-Massive felldspar.
Cilester. - Pyrite, tourmaline, rutile, chalcopyrite.
Diamond Isle (Lake George).-Caicite, quartz crystuls.
Glenn's Falls.-Rhomb spar.
Joirnsbura.-F'luorite! zircon!! graphitc, serpentine, pyrite.
WASIIINGTON CO.-Fort Ann.-Graphite, serpentine.
Granville.-Lamellar pyroxene, massive feldspar, epidote.
WAYNE CO.-WoLCOTT.-Barite.

WRSTCHESTER CO.-ANTHoNy's Nose.-Apatite, pyrite, calcite! in very large tabular crystals, grouped, and sometimes incrusted with drusy quartz.

Davenport's Neck.-Serpentine, garnet, sphene.
Eastciester.-Blende, pyrite, chalcopyrite, dolomite.
Hastings.-T'remolite, white pyroxene.
New Rocilelle.-Serpentive, brucite, quaitz, mica, tremolite, garnet, magnesite.
Peekskill.-Mica, feldspar, hornblende, stilbite, sphene; three miles south, emery.
Rre.-Serpentine, chlorite, bluck tourmaline, tremolite.
Singsing.-Pyroxene, tremolite, pyrite, beryl, azurite, green malachite, cerussite, pyromor phite, anglesite, vauquelinite, galenite, native silver, chalcopyrite.

West Farms.-Apatite, treinolite, garnet, stilbite, heulandite, chabazite, epidote, sphene Yonkers-Tremolite, apatite, calcite, analcite, pyrite, tourmaline.
Yonktown.-Sillimanite, monazite, magnetite.

## NEW JERSEY.

Andover Iron Mine (Sassex Co.).-Willemite, brown garnet.
Allentown (Monmouth Co.).-Vivianite, dufrenite.
Belville.-Copper mines.
Bergen.-Calcite! datolite! pectolite (called stellite)! analcite, apophyllite! gmelinite, prelinite, sphene, stilbite, natrolite, heulandite, laumontite, chabazite, pyrite, pseudomorphous steatite, imitative of apophyllite, diabantite.

Buonswick.-Copper mines; native copper, malachite, mountain leather.
Bryam.-Chondrodite, spinel, at Roseville, epidote.
Cantwelle's Bridge (Newcastle Co.), three miles west. - Vivianite.
Danville (Jemmy Jump Ridge).-Graphite, chondrodite, augite, mica.
Flemington.-Copper mines.
Frankfort.-Serpentine.
Franklin and Sterling.-Spinel! garnet! rhodonite! voillemite! franklinite!zincite! dysluite! hornblende, tremobite. chondrodite, white scapolite, black tourmaline, epidote, pink calcite, mica, actinolite, augite, sahlite, coccolite, asbestus, jeffer'sonite (augite), calamine, graphite, fluorite, beryl, galenite, serpentine, honey-colored sphene, quartz, chalcedony, amethyst, zircon, molybdenite, vivianite, tephroite, rhodochrosite, aragonite, sussexite, chalcophanite, rœpperite, calcozincite, vanuxemite, gahnite. Also algerite in gran. limestone.

Franklin and Warwick Mts.-Pyrite.
Greenibrook.-Copper mines.
Giriggstown.-Copper mines.
Hamburgir.-One mile north, spinel! tourmaline, phlogopite, hornblende, limonite, hematite.
Hoboken.-Serpentine (marmolite), brucite, nemalite (or fibrous brucite), aragonite, dolomite.

Hurdstown.-Apatite, pyrrhotite, magnetite.
Imleytown.-Vivianite.
Lockwoon.-Graphite, chondradite, talc, augite, quartz, green spinel.
Montville (Morris Co.).-Serpentine, chrysotile.
Mullica Hill (Gloucester Co.).-Vivianite lining belemnites and other fossils.
Newton.-Spinel, blue, pink, and white corundum, mica, vesuvianite, hornblende, tourmaline, scapolite, rutile, pyrite, talc, calcite, barite, pseudomorphous steatite.

Paterson.-Datolite.
Vernon.-Serpentine, spinel, hydrotalcite.

## PENNSYLVANIA.*

## adams co.-Gettrsburg.-Epidote, fibrous and massive.

berks Co.-Morgantown.- $\Lambda$ t Jones's mines, one mile east of Morgantown, green malachite, native copper, chrysocolla, magnetite, allophane, pyrite, chalcopyrite, aragonite. apatite, talc; two miles N.E. from Jones's mine, graphite, sphene; at Steele's mine, one mile N.W. from St. Mary's, Chester Co., magnetite, micaceous iron, coccolite, brown garnet. Reading.-Smoky quartz"crystals, zircon, stilbite, iron ore, near Pricetown, zircon, allanIte, epidote; at Eckhardt's Furnace, allanite with zircon; at Zion's Church, molybdenite;

* See also the Report on the Mineralogy of Pennsylvania, by Dr. F A. Genth, $187 \overline{0}$.
near Kutztown, in the Crystal Cave, stalactites; at Fritz Island, aponhyllite, thomsonite, chaba site, calcite, azurite, malachite, magnetite, chalcopyrite, stibnite, prochlorite, precious ser pentine.

BUCKS CO.-Buckingaram Townsuip.-Crystallized quartz; near New Hope, vesuvian ite, epidote, barite.

Southampton.-Near the village of Feasterville, in the quarry of George Van Arsdale; graphite, pyroxene, sahlite, coccolite, sphene, green mica, calcite, wollastonite, glassy feld spar sometimes opalescent, phlogopite, blue quartz, garnet, zircon, pyrite, moroxite, scapolite

New Briminn.-Dolomite, galenite, blende, malachite.

## CARBON CO.-Summit Hill, in coal mines.-Kaolinite.

CHESTER CO.-Avondaice.-Asbestus, tremolite, garnet, opal.
Birmingilam Townsiifp.-Amethyst, smoky quartz, serpentine, beryl ; in Ab'm Darling. ton's lime quarry, calcite.

East Bradford.-Near Buffington's bridge, on the Brandywine, green, blue, and gray cyanite, the gray cyanite is found loose in the soil, in crystals; on the farms of Dr. Euwyn, Mrs. Foulke, Wm. Gibbons, and Saml. Entrikin, amethyst. At Strode's mill, asbestus, magnesite, anthophyllite, epidote, aquacrepitite, oligoclase, drusy quartz, collyrite? on Osborne's Hill, wad, manganesian garnet (massive), sphere, schorl ; at Caleb Cope's lime quarry, fetid dolomite, necronite, garnets, blue cyanite, yellow actinolite in talc; near the Black Horse Inn, indurated talc, rutile; on Amor Davis' farm, orthite! massive, from a grain to lumps of one pound weight; near the paper-mill on the Brandywine, zircon, associated with titaniferous iron in blue quartz.

West Bradford. - Near the village of Marshalton, green cyanite, rutile, scapolite, pyrite, staurolite; at the Chester County Poor-house limestone quarry, chesterlite! in crystals implanted on dolomite, rutile! in brilliant acicular crystals, which are finely terminated, calcite in scalenohedrons, zoisite, damourite? in radiated groups of crystals on dolomite, quartz crystals; on Smith \& McMullin's farm, epidote.

Charlestown.- Pyromorphite, cerussite, galenite, quartz.
Coventry.-Allanite, near Pughtown.
Soutir Coventry.-In Chrisman's limestone quarry, near Coventry village, augite. sphene, graphite, zircon in iron ore (about half a mile from the village).

East Fallowfield.-Soapstone.
East Gosifen.-Serpentine, asbestus, magnetite (loadstone), garnet.
Elk.-Menaccanite with muscovite, chromite ; at Lewisville, black tourmaline.
West Goshen.-On the Barrens, one mile north of West Chester, amianthus, serpentine, cellular quartz, jasper, chalcedony, drusy quartz, chlorite, marmolite, indurated talc, magnesite in radiated crystals on serpentine. hematite, asbestus ; near R. Taylor's mill, chromite in octahedral crystals, deweylite, radinted magnesite, aragonite, staurolite, garnet, asbestus, epidote; zoisite on hornblende at West Chester water-works (not accessible at present).

New Garden.-At Nivin's limestone quarry, brown tourmaline, necronite, scapolite, apatite, brown and green nica, rutile, aragonite, fibrolite, kicolinite, tremolite.

Kennett.-Actinolite, brown tourmaline, brown mica, epidote, tremolite, scapolite, aragonite ; on Wm. Cloud's farm, sunstone! ! chabazite, sphene. At Pearce's old-mill, zoisite, epuidote, sunstone; sunstone occurs in good specimens at various places in the range of hornblende rocks running through this township from N E. to S.W.

Lower Oxford.-Garnets, pyrite in cubic crystals.
London Grove.-Rutile, jasper, chalcedony (botryoidal), large and rough quartz crystals, epidote; on Wm. Jackson's farm, yellow and black tourmaline, tremolite, rutile, green mica, apatite, at Pusey's quarry, rutile, tremolite.

East Marlboro Ugir.-On the farm of Baily \& Brothers, one mile south of Unionville, bright yellow and nearly white torimalne, chesterlite, albite, pyrite ; near Marlborough meet-ing-house, epidote, serpentine, acicular black tourmaline in white quartz; zircon in small perfect crystals, loose in the soil at Pusey's saw-mill, two miles S.W. of Unionville.

West Marlborovair. - Near Logan's quarry, staurolite, cyanite, yellow tourmaline, rutile, garnets; near Doe Run village, hematire, scapolite, tremolite ; in R. Baily's limestone quarry, two and a half miles S.W. of Unionville, fibrous tremolite, cyanite, scapolite.

Newlin.- On the serpentine barrens, one and a half mile N.E. of Unionville, corundum ! massive and crystallized, also in crystals in albite, often in loose crystals covered with a thin coating of steatite, spinel (black), talc, picrolite, brucite, green tourmaline with flat pyramidal terninations in albite, unionite (rare) euphyllite. mica in hexagonal crystals, feldspan
beryl! in hexagona: crystals, one of which weighs 51 lbs , pyrite in crbic crystals, chromic iron, drusy quartz, green quartz, actinolite, emerylite, chloritoid, diallage, oligoclase; on Johnson Patterson's farm, massive corundum, titaniferous iron, clinochlore, emerylite, sometimes colored green by chrome, albite, orthoclase, halloysite, margarite, garnets, beryl; on J. Lesley's farm, corundum, crystallized and in massive lumps, one of which weighea 5,200 lbs., diaspore! ! emerylite! euphyllite crystallized! green tourmaline, transparent crystals in the euphyllite, orthoclase; two miles N. of Unionville, magnetite in octahedral crystals; one mile E. of Unionville, hematite; in Edwards's old limestone quarry, purple fluorite, rutile.

East Nottingitam. - Sand chrome, asbestus, chromite in octahedral crystals, hallite, beryl.
West Nottingham. - At Scott's chrome mine, chromite, foliated talc, marmolite, serpen tine, chalcedony, rhodoclirome; near Moro Phillip's chrome mine, asbestus; at the magnesia quarry, dexeylite, marmolite, magnesite, leelite, serpentine, sand chrone; near Fremont P.O., corundum.

East Pikeland.-Iron ore.
West Pikeland. - In the iron mines near Chester Springs, gibbsite, zircon, turgite, heinatite (stalactitical aud in geodes), göthite.

Penn.-Garnets, agalmatolite.
Pennsbury.-On John Craig's farm, brown garnets, mica; on J. Dilworth's farm, near Fairville, muscovite! in hexagonal prisms from one-quarter to seven inches in diameter; in the village of Fairville, sunstone; near Brinton's ford, on the Brandywine, chondrodite, splienc, diopside, augite, coccolite; at Mendenhall's old limestone quarry, fetid quartz, sunstone ; at Swain's quarry, crystals of orthoclase.

Pocopson.-On the farms of John Entrikin and Jos. B. Darlington, amethyst.
Sadsbury.--Rutile!! splendid geniculated crystals are found loose in the soil for seven miles along the valley, and particularly near the village of Parkesburg, where they sometimes occur weighing one pound, donbly geniculated and of a deep red color; near Sadsbury village, amethyst, tourmaline, epidote, milk quartz.

Sciluylikill.-In the railroad tunnel at Pheenixville, dolomite! sometimes coated with pyrite, quartz crystals, yellow blende, brookite, calcite in hexagonal crystals enclosing pyrite; at the Wifeatley, Brookdale, and Cifester County lead mines, one and a half mile S. of Phœnixville, pyromorphite! cerussite! galenite, anglesite!! quartz crystals, chalcopyrite, barite, fluorite (white). stolzite, wulfenite! calamine, vanadinite, blende! mimetite! descloizite, göthite, chrysocolla, native copper, malachite, azurite, limonite, calcite, sulphur, pyrite, melaconite, pseudomalachite, gersdorffite, chalcocite? covellite.

Tifornbury.-On Jos. H. Brinton's farm, muscovite containing acicular crystals of tourmaline, rutile, titaniferous iron.

Tredyffrin - Pyrite in cubic crystals loose in the soil.
Uwcillan.-Massive blue quartz, graphite.
Warren.-Melanite, feldspar.
West Gosiren (one mile from West Chester).-Chromite.
Willistown.-Magnetite, chromite, actinolite, asbestus.
West-Town.-On the serpentine rocks, 3 miles S. of West Chester, clinochlore ! jefferisite ! mica, asbestus, actinolite, magnesite, tabc, titaniferous iron, magnetite and massive tourmaline.

East Whiteland. - Pyrite, in very perfect cubic crystals, is found on nearly every farm in this township, quartz crystals found loose in the soil.

West Whiteland.-At Gen. Trimble's iron mine (south-east), stalactitic hematite! varellite!! ! in radiated stalactites, gibbsite, cœruleolactile.

Warwick.-At the Elizabeth mine and Keim's old iron mine adjoining, one mile N. of Knauertown, aplome garnet! in brilliant dodecahedrons, flosforri, pyroxene, micaceous hematite, pyrite in bright octahedral crystals in calcite, chrysocolla, chalcopyrite massive and in single tetrahedral crystals, magnetite, fascicular hornblende! bornite, malachite, brown garnet, calcite, byssolite! serpentine; near the village of St. Mary's, magnetite in dodecahedral crystals, melanite, garnet, actinolite in small radiated nodules; at the Hopewell iron mine, one mile N.W. of St. Mary's, magnetite in octahedral crystals.

COLUMBIA CO.-At Webb's mine, yellow blende in calcite ; near Bloomburg, cryst. mag netite.

## DaUPHIN CO.-Near Hummerstown.-Green garnets, cryst. smoky quartz, feldspar.

DELAWARE CO.-Aston Townsmip. - Amethyst, corunclum, emerylite, staurolite, fibra lite, black tourmaline, margarite, sunstone, asbestus, anthophyllite, steatite • near '「yson'я mill, garnet, staurolite ; at Peter's mill-dam in the creek, pyrope garnet.

Birmingham. - Fibrolite, kaolin (abundant), crystals of rutile, amethyst; at Bullock's old quarry, zircon, bucholzite, nacrite, yellow crystallized quartz, feldspar.

Blue Hill.-Green quartz crystals, spinel.
Chestrir.-Amethyst, black tourmaline, beryl, crystals of feldspar, garnet, cryst. pyrite, molybdenite, molybdite, chalcopyrite, kaolin, uraninite, muscovite, orthoclase, bismutite.

Cificifester.-Near Trainer's mill-dam, beryl, tourmaline, crystals of feldspar, kaolin; on Wm. Eyre's farm, tourmaline.

Concord.-Crystals of mica, crystals of feldspar, kaolin abundant, drusy quartz of a blue and green color, meerschaum, stellated tremolite, some of the rays $6 \frac{1}{2} \mathrm{in}$. diameter, antho. phyllite, fibrolite, acicular crystals of rutile, pyrope in quartz, amethyst, actinolite, mangane. sian garnet, beryl: in Green's creek, pyrope garnet.

Darby.-Blue and gray cyanite, garnet, staurolite, zoisite, quartz, beryl, chlorite, mica, limonite.

Edgemont.-Amethyst, oxide of manganese, crystals of feldspar; one mile east of Edge mont Hall, rutile in quartz.

Green's Creek.-Garnet (so-called pyrope).
Haverford.-Staurolite with garnet.
Marple.-Tourmaline, andalusite, amethyst, actinnlite, anthophyllite, talc, radiated actin. olite in talc, chromite, drusy quartz, beryl, cryst. pyrite, menacsanite in quartz, chlorite.

Middletown.-Amethyst, beryl, black mica, mica with reticulated magnetite between the plates, manganesian garnets! large trapezohedral crystals, some 3 in . in diameter, indurated talc, hexagonal crystals of rutile, crystals of mica, green quartz! anthophyllite, radiated tourmaline, staurolite, titanic iron, fibrolite, serpentine; at Lenni, chlorite, gıeen and bronze vermiculite! green feldspar ; at Mineral Hill, fine crystals of corundum, one of which weighs $1 \frac{9}{4} \mathrm{lb}$., actinolite in great variety, bronzite, green feldspar, moonstone, sunstone, graphic granite, magnesite, octakedral crystals of chromite in great quantity, beryl, chalcedony, asbestus, fibrous hornblende, rutile, staurolite, melanosiderite, hallite; at Painter's Farm, near Dismal Run, zircon with oligoclase, tremolite, tourmaline; at the Black Horse, near Media, corundum; at Hibbard's Farm and at Fairlamb's Hill, chromite in brilliant octahedrons.

Newtown.-Serpentine, hematite, enstatite, tremolite.
Upper Providence.-Anthophyllite, tremolite, radiated asbestus, radiated actinolite, tour. maline, beryl, green feldspar, amethyst (one found on Morgan Hunter's farm weighing over 7 lbs.), andalusite! (one terminated crystal found on the farm of Jas. Worrall weighs $7 \frac{1}{2} \mathrm{lbs}$.) ; at Blue Hill, very fine crystals of blue quartz in chlorite, amianthus in serpentine, zircon.

Lower Providence.-Amethyst, green mica, garnet, large crystals of feldspar! (some over 100 lbs . in weight).

RADNOR.-Garnet, marmolite, deweylite, chromite, asbestus, magnesite, tale, blue quartz, picrolite,-limonite, magnetite.

Springfield.-Andalusite, tourmaline, beryl, titanic iron, garnet; on Fell's Laurel Hill, beryl, garnet ; near Beattie's mill, staurolite, apatite; near Lewis's paper-mill, tourmaline, mica.

Thornbury.-Amethyst.
HUNTINGDON CO. -Near Frankstown. - In the bed of a stream and on the side of a hill, fibrous celestite (abundant), quartz crystals.

## LANCASTER CO.-Drumore Township.-Quartz crystals.

Fulton.-At Wood's chrome mine, near the village of Texas, brucite ! ! zaratite (emerald nickel), pennite! ripidolite! kümmererite! briltimorite, chromic iron, williamsite, chrysolite! marmolite, picrolite, hydromagnesite, dolomite, magnesite, aragonite, calcite, serpentine, hematite, menaccanite, genthite, chrome-garnet, bronzite, millerite; at Low's mine, hydromagnesite, brucite (lancasterite), picrolite, magnesite, williamsite, chromic iron, talc, zaratite, baltimorite, serpentine, hematite ; on M. Boice's farm, one mile N.W. of the village, 'pyrite in cubes and various modifications, anthophyllite; near Rock Springs, chalcedony, carnelian, moss agate, green tourmaline in talc, titanic iron, chromite, octakedral magnetite in chlorite; at Reynolds's old mine, calcite, talc, picrolite, chromite; at Carter's chrome mine, brookite.

Gap Mines.-Chalcopyrite, pyrrhotite (niccoliferous), millerite in botryoidal radiations, vivianite! (rare), actinolite, siderite, hisingerite, pyrite.

Pequea Valley. - Eight miles south of Lancaster, argentiferous galenite (said to contain 250 to 300 ounces of silver to the ton?), vauquelinite, rutile at Pequea mine; forr miles N.W. of Lancaster, on the Lancaster and Harrisburg Railroad, calamite, galenite, blende ; pyrite ir mbic crystals is found in great abundance near the city of Lancaster; at the Lancaster zine mines, calamine, blende, tennantite? srithsonite (pseud. of dolomite), aurichalcite.

LEBAN()N CO.-CorNwall.-Magnetite, pyrite (cobaltiferous), chalcopyrite, native copper, azurite, malachite, chrysocolla, cuprite (hydrocuprite), allophane, brochantite, serpentine, quartz pseudomorphs; galenite (with octahedral cleavage), tluorite, covellite, hemazite (mi caceous), opal, asbestus.

LEHIGFI CO -Friedensville.-At the zinc mines, alamine, smithsonite, hydrozincite, massive blende, greenockite, quartz, allophane, zinciferous clay, mountain leather, aragonite, sauconite; near Allentown, magnetite, pipe-iron ore; near Bethlehem, on S. Mountain, allanite, with zircon and altered sphene in a single isolated mass of syenite, magnetite, martite, black spinel, tourmaline, chalcocite.

MIFFLIN CO.-Strontianite.
MONROE CO.-In Cinetry Valley.-Calcite, chalcedony, quartz; in Poconac Valley, near Judge Mervine's, cryst. quartz.

MONTGOMERY CO.-ConsHoHocken.-Fibrous tourmaline, menaccanite, aventurine quartz, phyllite; in the quarry of Geo. Bullock, calcite in hexagonal prisms. aragonite.

Lower Providence.-At the Perkiomen lead and copper mines, near the village of Shannonville, azurite, blende, galenite, pyromorphite, cerassite, wulfenite, anglesite, barite, calamine, chalcopyrite, malachite, chrysocolla, brown spar, cuprite, covellite (rare), melaconite, libethenite, pseudomalachite.

Wirite Marsif.-At D. O. Hitner's iron mine, five and a half miles from Spring Mills, limonite in geodes and stalactites, göthite, pyrolusite, wad, lepidocrocite; at Edge Hill Street, North Pennsylvania Railroad, titanic iron, braunite, pyrolusite; or:e mile S. W. of Hitner's iron mine, limonite, velvcty, stalactitic, and fibrous, fibres three inches long, turgite, güthite, pyrolusite, velvet manganese, wad ; near Marble Hall, at Hitner's marble quarry, white marble, granular barite, resembling marble; at Spring Mills, limonite, pyrolusite, göthite ; at Flat Rock Tuunel, opposite Manayunk, stilbite, heulandite, chabasite, ilvaite, beryl, feldspar, mica.

Lafayette, at the Soapstone quarries.-Talc, jefferisite, garnet, albite, serpentine, zoisite, staurolite, chalcopyrite ; at Rose's Serpentine quarry, opposite Lafayette, enstatite, serpentine.

NORTHUMBERLAND CO.-Opposite Selim's Grove.-Calamine.
NORTHAMPTON CO.-Bushkill Township.-Crystal Spring on Blue Mountain, quartz crystals.

Near Easton.-Zircon! (exhausted), nephrite, coccolite, tremolite, pyrcxene, sablite, limonite, magnetite, purple calcite.

Williams Townsuip.-Pyrolusite in geodes in limonite beds, göthite (lepidocrocite) at Glendon.

PHILADELPHIA CO.-Frankford.-Titanite in gneiss, apophyllite ; on the Philadelphia, Trenton and Connecting Railroad, basanite; at the quarries on Frankford Creek, stilbite, molybdenite, hornblende ; on the Connecting Railroad, wad, earthy cobalt ; at Chestnut Hill, magnetite, green mica, chalcopyrite, fluorite.

Fairmount Water Works.-In the quarries opposite Fairmount. autunite! torbernite crystals of feldspar, beryl, pseudomorphs after beryl, tourmaline, albite, wad, menaccanite. Gorgas' and Crease's Lane. -Tourmaline, cyanite, staurolite, hornstone.
Near Germantown.-Black tourmaline, laumontite, apatite; York Road, tourmaline, beryl.
Hestonville. - Alunogen, iron alum, orthoclase.
Heft's Mill.-Alunogen, tourmaline, cyanite, titanite.
MANAYUNK.-At the soapstone quarries above Manayunk, tale, steatite, chlorite, vermiculite, anthophyllite, staurolite, dolomite, apatite, asbestus, brown spar, epsomite.
Meagaraee's Paper-mill.-Staurolite, titanic iron, hyalite, apatite, green mica, iron garnets in great abundance.
McKinNeY's Quarry, on Rittenhouse Lane.-Feldspar, apatite, stilbite, natrolite, heulandite, epidote, hornbleude, erubescite, malachite.

Scifullilll Falls.-Chabazite, titanite, flworite, epidote, muscovite, tourmaline, prochlorite.
§chuylikill CO.-Tamaqua, near Pottsville, in coal mines.-Kaolinite.
YGRK CO.-Bornite, rutile in slender prisms in granular quartz, calcite.

## DELAWARE.

NEWCASTLIE CO.-Brandywine Springs.-Bucholzite, fibrolite abundant, sahlite, pyroz ene; Brandywine Hundred, muscovite, enclosing reticulated magnetite.

Dixon's Feldspar Quarries, six miles N. W. of Wilmington (these quarries have been worked for the manufacture of porcelain).-Adularia, albite, oligoclase, beryl, apatite, cinna-mon-stone! ! (both granular like that from Ceylon, and crystallized, rare), magnesite, serpentine, asbestus, black tourmaline! (rare), indicolite! (rare), sphene in pyroxene, cyanite.

Dupont's Powder Mills. - "Hypersthene."
Eastburn's Limestone Quarries, near the Pennsylvania line.-Tremolite, bronzite.
Quarryville.--Garnet, spodumene, fibrolite.
Near Newark, on the railroad.-Sphærosiderite on drusy quartz, jasper (ferruginous opal), cryst. spathic iron in the cavities of cellular quartz.

Way's Quarky, two miles south of Centreville.-Feldspar in fine cleavage masses, apatite. mica, deweylite, granular quartz.

Wilmington.-In Christiana quarries, metalloidal diallage.
Kennett Turnpike, near Centreville.-Cyanite and garnet.
HARFORD CO.-Cerolite.
KENT CO.-Near Middletown, in Wm. Polk's marl pits.-Vivianite !
On Chesareake and Delaware Canal.-Retinasphalt, pyrite, amber.
sussex Co.-Near Cafe Henlopen - Vivianite.

## MARYLAND.

Baltimore (Jones's Falls, 1蒌 mile from B.). -Chabazite (haydenite), heulandite (beara montite of Levy), pyrite, lenticular carbonate of iron, mica, stilbite.

Sixteen miles from Baltimore, on the Gunpowder.-Graphite.
Twenty-three miles from B., on the Gunpowder.-Talc.
Twenty-five miles from B., on the Gunpowder.-Magnetite, sphene, pycnite.
Thirty miles from B., in Montgomery Co., on farm of S. Eliot.-Gold in quartz.
Eight to twenty miles north of B., in limestone.-Tremolite, augite, pyrite, brown and yel low tourmaline.

Fifteen miles north of B.-Sky-blue chalcedony in granular limestone.
Eighteen miles north of B., at Scott's mills.-Magnetite, cyanite.
Bare Hills.-Chromite, asbestus, tremolite, talc, hornblende, serpentine, chalcedony, meerschaum, baltimorite, chalcopyrite, magnetite.

Cape Sable, near Magothy R.-Amber, pyrite, alum slate.
Carroll Co.-Near Sykesville, Liberty Mines, gold, magnetite, pyrite (octahedrons), chalcopyrite, linnæite (carrollite); at Patapsco Mines, near Finksburg, bornite, malechite, siegenite, linnaite, remingtonite, magnetite, chalcopyrite ; at Mineral Hill mine, bornite, chalcopyrite, ore of nickel (see above). gold, magnetite.

Cecil Co., north part.-Chromite in serpentine.
Cooptown, Harforả Co.-Olive-colored tourmaline, diallage, talc of green, blue, and rose colors, ligniform asbestus, chromite, serpentine.

Deer Creek.-Magnetite! in chlorite slate.
Frederick Co.-Old Liberty mine, near Liberly Town, black copper, malachite, chalcocile, specular iron; at Dollyhyde mine, bornite, chalcopyrite, pyrite, argentiferous galenite in dolomite.

Montgomery Co.-Oxide of manganese.
Somerset and Woncester Cos., north part.-Bog-iron ore, vivianite.
St. Mary's River.-Gypsum! in clay.
Pylesville, Harford Co.-Asbestus mine.

## VIRGINIA AND DISTRICT OF COLUMBIA.

Albemarlef Co., a little west of the Green Mts. - Steatite, graphite, galenite.
Amierst Co., along the west base of Buffalo ridge.-Copper ores, allanite, etc.
Augusta Co.-At Weyer's (or Weir's) cave, sixteen miles northeast of Staunton, and
oighty-one miles northwest of Richmond, calcite, stalactites.

Buckingham Co.-Gold at Garnett and Moseley mines, also, pyrite, pyrrhotite, calcite, garnet ; at Eldridge mine (now London and Virginia mines) near by, and the Buckingham mines near Maysville, gold, auriferous pyrite, chalcopyrite, tennantite, barite ; cyanite, tourmaline, actinolite.

Ciresterfield Co.-Near this and Richmond Co. bituminous coal, native coke.
Culpepper Co., on Rapidan river.-Gold, pyrite.
Franklin Co.-Grayish steatite.
Fauquier Co., Barnett's mills.-Asbestus, gold mines, barite, calcite.
Fluvanna Co.-Gold at Stockton's mine; also tetradymite at "Tellurium mine."
Pientr Copper mines.-Chalcopyrite, etc.
Georgetown, D. C.-Rutile.
Goocmland Co.-Gold mines (Moss and Busby's).
Harper's Ferry, on both sides of the Potomac. -Thuringite (owenite) with quartz.
Jefferson Co., at Shepherdstown. - Fluor.
Kenawira Co.-At Kerawha, petroleum, brine springs, cannel coal.
Loudon Co.-Trabular quartz, drase, pyrite, talc, chlorite, soapstone, asbestus, chromite, actinolite, quartz crystals; micaceous iron, bornite, malachite, epidote, near Leesburg (Potomac mine).

Louisa Co.-Walton gold mine, gold, pyrite, chalcopyrite, argentiferous galenite, siderite, blende, anglesite ; boulangerite, blende (at Tinder's mine).

Nelson Co.-Galenite, chalcopyrite, malachite.
Orange Co.-Western part, Blue Ridge, specular iron; gold at the Orange Grove and Vaucluse gold mines, worked by the "Freehold" and "Liberty" Mining Companies.

Rockbridge Co., three miles southwest of Lexington.-Barite.
Silenandoait Co., near Woodstock.-Fluorite.
Mt. Alto, Blue Ridge.-Argillaceous iron ore.
Spottsylvania Co., two miles northeast of Chancellorville. - Cyanite; gold mines at the junction of the Rappahannock and Rapidan; on the Rappahannock (Marshall mine); Whitehall mine, affording also tetradymite.

Stafford Co., eight or ten miles from Falmouth-Micaceous iron, gold, tetradymite, silver, galenite, vivianite.

Wasiington Co., eighteen miles from Abington.-Rock salt with gypsum.
Wytire Co. (Austin's mines).-Cerussite, minium, plumbic ochre, blende, calamine, galcnite, graphite.

On the Potomac, twenty-five miles north of Washington city.-Natice sulphur in gray compact limestone.

## NORTH CAROLINA.

Asme Co.-Malachite, chalcopyrite.
Buncombe Co., (now called Madison Co).-Corundum (from a boulder), margarite, cornndophilite, garnet, chromite, barite, fluorite, rutile, iron ores, manganese, zircon; at Swannanoa Gap, cyanite.

Burke Co.-Gold, monazite, zircon, beryl, corundum, garnet, sphene, graphite, iron ores, tetradymite, montanite.

Cabakrus Co.-Phenix Mine, gold, barite, chalcopyrite, auriferous pyrite, quartz, pseudomorph after barite. tetradymite, montanite; Pioneer mines, gold, limonite, pyrolusite, barnhardite, wolfram, scheelite, cuprotungstite, tungstite, diamond, chrysocolla, chalcocite, molybdenite, chalcopyrite, pyrite; White mine, needle ore, chalcopyrite, barite; Long and Muse's mine, argentiferous galenite, pyrite, chalcopyrite, limonite ; Boger mine, tetradymite; Fink mine, valuable copper ores; Mt. Makins, tetrahedrite, magnetite, talc, blende, pyrite, prous tite, galenite ; Bangle mine, scheelite.

Caldwelil Co.-Chromite.
Cilatiam Co.-Mineral coal, pyrite, chloritoid.
Cherokee Co.-Iron ores, gold, galenite, corundum, rutile, cyanite, damonite.
Gleveland Co.-White Plaius, quertz, crystals, smoky quartz, tourmaline, rutile in quartz.
Clay Co.-At the Cullakenee Mine and elsewhere, corundum (pink), zoisite, tourmaline, margarite, willcoxite, dudleyite.
Davidson Co.-King's, now Washin ${ }_{\circ}{ }^{\text {ton }}$ mine, native, silver, cerussite, anglesite, scheelite, promorphite, galenite, blende, malachite, black copper, wavellite, garnet, stilbite; five mile from Washington mine, on Faust's farm, gold, tetradymite, oxide of bismuth and tellurium, montanite, chalcopyrite, limonite, spathic iron, epidote; near Squire Ward's, gold in crystals, electrum.
Franklin Co.-At Partiss mine, diamonds.
Gaston Co.-Iron ores, corundum, margarite; near Crowder's Mountain (in what was
formerly Lincoln Co.), lazulite, cyanite, garnet, graphite ; also twenty miles northeast, neat south end of Clubb's Mtn., lazulite, cyanite, talc, rutile, topaz, pyrophyilite; King's Mountain (or Briggs) Mine, native tellurium, altaite, tedradymite, montanite.

Guilford Co.-McCulloch copper and gold mine, twelve miles from Greensboro', gold, pyrite, chalcopyrite (worked for copper), quartz, siderite. The North Carolina Copper Co. are working the copper ore at the old Fentress mine; at Deep River, compact pyrophyllite (worked for slate-pencils).
Haywood Co.-Corundum, margarite, damourite.
Henderson Co.-Zircon, sphene (xanthitane).
Jackson Co.-Alunogen? at Smoky Mt.; at Webster, serpentine, chromite, genthite, shrysolite, talc; Hoghalt Mt., pink corundum, margarite, tourmaline.
Lincoln Co.-Diamond; at Randleman's, amethyst, rose quartz.
Macon Co.-Franklin, Culsagee Mine, corundum, spinel, diaspore, tourmaline, damourite, prochlorite, culsageeite, kerrite, maconite.

McDowell Co.-Brookite, monazite, corundum in small crystals red and white, zircons, garnet, beryl, sphene, xenotime, rutile, elastic sandstone, iron ores, pyromelane, tetradymite, montanite.
Madison Co.-20 miles from Asheville, corundum, margarite, chlorite.
Mecklenburg Co.-Near Charlotte (Rhea and Cathay mines) and elsewhere, chalcopyrite, gold ; chalcotrichite at McGinn's mine; barnhardtite near Charlotte; pyrophyllite in Cotton Stone Mountain, diamond; Flowe mine, scheelite, wolframite ; Todd's Branch, monazite.

Mitchell Co.-Samarskite, pyrochlore (?), euxenite, columbite, muscovite.
Montgomery Co.-Steele's mine, ripidolite, albite.
Moore Co.-Carbonton, compact pyrophyllite.
Rowan Co.-Gold Hill Mines, thirty-eight miles northeast of Charlotte, and fourteen from Salisbury, gold, auriferous pyrite ; ten miles from Salisbury, feldspar in crystals, bismuthinite.
Randolpi Co.-Pyrophyllite.
Rutherford Co.-Gold, graphite, bismuthic gold, diamond, euclase, pseudomorphonıs quartz?, chalcedony, corundum in small crystals, epidote, pyrope, brookite, zircon, monazite, rutherfordite, samarskite, quartz crystals, itacolumyte; on the road to Cooper's Gap, cyanite.

Stokes and Surry Cos. -Iron ores, graphite.
Union Co.-Lemmond gold mine, eighteen miles from Concord (at Stewart's and Moore's mine), gold, quartz, blende, argentiferous galenite (containing 29.4 oz . of gold and 86.5 oz . of silver to the ton, Genth), pyrite, some chalcopyrite.

Yancey Co. -Iron ores, amianthus, chromite, garnet (spessartite), samarskite.

## SOUTH CAROLINA.

Abbeville.-Dist.-Oakland Grove, gold (Dorn mine), galenite, pyromorphite, amethyst, garnet.
ANDERSOM DIST.-At Pendleton, actinolite, galenite, kaolin, tourmaline.
Cifarleston.-Selenite.
Cieowee Valley. - Galenite, tourmaline, gold.
Cifesterfield Dist.-Gold (Brewer's mine), talc, chlorite, pyrophyllite, pyrite, native
bismuth, carbonate of bismuth, red and yellow ochre, whetstone, euargite.
Darlington.-Kaolin.
Edgefield Dist.-Psilomelane.
Greenville Dist.-Galenite, pyromorphite, kaolin, chalcedony in buhrstone, beryl, plumbago, epidote, tourmaline.

Kersiraw Dist.-Rutile.
Lancaster Dist.--Gold (Hale's mine), talc, chlorite, cyanite, elartic sandstone, pyrite; gold also at Blackman's mine, Massey's mine, Ezell's mine.

Laurens Dist.-Corundum, damourite.
Newberry Dist.-Leadhillite.
Picken's Dist.-Gold, manganese ores, kaolin.
Ricilland Dist. - Chiastolite, novaculite.
Spartanburg Dist.-Magnetite, chalcedony, himatite; at the Cowpens, limonite, graphita
limestone, copperas; Morgan mine, leadhillite, pyromorphite, cerussite.
Sumter Dist.-Agate.
Union Dist.-Fairforest gold mines, pyrite, chalcopyrite.
Yokk Dist.-limestones, whetstones, witherite, barite, tetradymite.

## GEORGIA.

Burke and Scriven Cos.-Hyalite̊.
Cheroree Co.-At Canton Mine, chalcopyrite, galenite, clausthalite, plumbogunmite, nitchcockite, arsenopyrite, lanthanite, harrisite, cantonite, pyromorphite, automolite, zinc, staurolite, cyanite ; at Ball-Ground, spodumene.

Clamk Co., near Clarksville.-Gold, xenotime, zircon, rutile, cyanite, hematite, garnet, quartz.
Dade Co.-Halloysite, near Rising Fawn.
Fannin Co.-Staurolite! chalcopyrite.
Habersiran Co. - Gold, pyrite, chalcopyrite, galenite, hornblende, garnet, quartz, kaolinite, soapstone, chlorite, rutile, iron ores, tourmaline, staurolite, zircon.

Hiall Co.-Gold, quartz, kaolin, diamond.
Hancock Co.-Agate, chalcedony.
Heard Co.-Molybdite, quartz.
Lincoln Co.-Luzulite!! rutile!! hematite, cyanite, menaccanite, pyrophyllite, gold, itacolumyte rock.

Lowns Co.-Corundum.
Lumpirin Co.-At Field's gold mine, near Dahlonega, gold, tetradymite, pyrrhotite, chlorite, menaccanite, allanite, apatite.

Rabun Co.-Gold, chalcopyrite.
Spaulding Co.-Tetradymite.
Washington Co., near Saundersville.-Wavellite, fire opal.

## ALABAMA.

Bibs Co., Centreville.-Iron ores, marble, barite, coal, cobalt.
Tuscaloosa Co.-Coal, galenite, pyrite, vivianite, limonite, calcite, dolomite, cyanite, steatite, quartz crystals, manganese ores.

Benton Co.-Antimonial lead ore (boulangerite?)
T'allapoosa Co., at Dudleyville.-Corundum, spinel, tourmaline.

## FLORIDA.

Near Tampa Bay.-Limestone, sulphur springs, chalcedony, carnelian, agate, silicified shells and corals.

## KENTUCKY.

Anderson Co.-Galenite, barite.
Clinton Co.-Geodes of quartz.
Crittenden Co.-Galenite, fluorite, calcite.
Cumberland Co.-At mammoth Cave, gypsum rosettes! calcite, stalactites, nitre, epsomite.

Fayette Co.-Six miles N.E. of Lexington, galenite, barite, witherite, blende.
Livingstone Co., near the line of Union Co.-Galenite, chalcopyrite, large vein of fluorite.
Mercer Co.-At McAfee, fluorite, pyrite, calcite, barite, celestite.
Owen Co.-Galenite, barite.

## TENNESSEE.

Brown's Creek.-Galenite, blende, barite, celestite.
Carter's Co., foot of Roan Mt. - Suhlite, magnetite.
Clahborne Co.-Calamine, galenite, smithsonite, chlorite, steatite, magnetite.
Cocke Co., near Brush Creek.-Cacoxene? kraurite, iron sinter, stilpnosiderite, brown hematite.

Davidson Co.-Selenite, with granular and snowy g?psum, or alabaster, crystallized and compact anhydrite, fluorite in crystals? calcite in crystals. Near Nashville, blue celestite, (crystallized, fibrous, and radiated), with barite in limestone. Haysboro', galenite, blende. with barite as the gangue of the ore.

Dickson Co.-Manganite.

Jefferson Cu.-Calamine, galenite, fetid barite.
Knox Co.-Magnesian limestone, native iron, variegated marbles !
Maury Co.-Wavellite in limestone.
Morgan Co.-Epsom salt, nitrate of lime.
Polk Co., Ducktown mines, southeast corner of State.-Melaconite, chalcopyrite, pyrite, native copper, bornite, rutile, zoisite, galenite, harrisile, alisonite, blende, pyroaene, tremolite, sulphates of copprr and iron in stalactites, allophane, rahtite, chalcocite (ducktownite), chalcotrichite, azurite, malachite, pyrrhotite, limonite.

Roan Co., eastern declivity of Cumberland Mts.-Wavellite in limestone.
Sevier Co., in caverns.-Epsom salt, soda alum, saltpetre, nitrate of lime, breccia marble.
Smitil Co.-Fluorite.
Smoky MT., on declivity.-Hornblende, garnet, staurolite.
White Co.-Nitre.

## OHIO.

Bainbridge (Copperas Mt., a few miles east of B.).-Calcite, barite, pyrite, copperas, alum.

Canfield.-Gypsum!
Duck Creek, Monroe Co.-Petroleum.
Lake Erie.-Strontian Island, celestite! Put-in Bay Island, celestite! sulphur! calcite. Liverpuol.-Petroleum.
Marietta.-Argillaceous iron ore ; iron ore abundant also in Scioto and Lawrence Cos. Ottawa Co.-Gypsum.
Poland.-Gypsum!

## MICHIGAN.

Brest (Monroe Co.).-Calcite, amethystine quartz, apatite, celestite.
Grand Rapids.-Selenite, fib. and granular gypsum, calcite, do'omite, anhydrite.
*Lake Superior Mining Region.-The four principal regions are Keweenaw Point, Isiée Royale, the Ontonagon, and Portage Lake. The mines of Keweenaw Point are along two ranges of elevation, one known as the Greenstone Range, and the other as the Southern or Bohemian Range (Whitney). The copper occurs in the trap or amygdaloid, and in the associated conglomerate. Native copper! native silver! chalcopyrite, horn silver, tetrahedrite, manganese ores, epidote, prehnite, laumontite, dutolite, heulandite, orthoclase, ana'cite, chabazite, compact datolite, chrysocolla, mesotype (Copper Falls mine), leonhardite (ib.), analcite (ib.), apophyllite (at Cliff mine), vollastonite (ib.), calcite, quartz (in crystals at Minnesota mine), compact datolite, orthoclase (Superior mine), saponite, melaconite (near Copper Harbor, but exhausted), chrysocolla ; on Chocolate River, galenite and sulphide of copper ; chalcopyrite and native copper at Presq' Isle ; at Albion mine, domeyluite ; at Prince Vein, barite, salcite, amethyst; at Michipinoten Ids., copper nickel, stilbite, analcite ; at Albany and Boston mine, Portage Lake, prehnite, analcite, orthoc'ase, cuprite; at Sheldon location, domeykite, whitneyite, algodonite ; Isle Royale mine, Portage Lake, compact datolite; Quincy mine, calcite, compact datolite. At the Spurr Mountain Iron mine (magnetite), chlorite pseudomorph after garnet.

Marquette.-Manganite, galenite ; twelve miles west at Jackson Mt., and other mines, hematite, limonite, göthite! magnetite, jasper.
Monroe.-Aragonite, apatite.
Point aux Peaux (Monroe Co.).-Amethystine quartz, apatite, celestite, calcite.
Saginaw Bay.-At Alabaster. gypsum.
Stony Point (Monroe Co.).-Apatite, amethystine quartz, celestite, calcite.

## ILLINOIS.

Gallatin Co., on a branch of Grand Pierre Creek, sixteeu to thirty miles from Shawneetown, down the Ohio, and from half to eight miles from this river. - Violet fluorite! in car boniferous limestone, barite, galenite, blende, brown iron ore.

Hancock Co.-At Warsaw, quartz geodes!' containing calcite! chalcedony, dolomite, blende:' brewn spar, pyrite, aragonite, gypsum, bitumen.

[^62]Hardin Co.-Near Rosiclare, calcite, galenite, blende; five miles back from Elizabeth town, bog-iron ; one mile north of the river, between Elizabethtown and Rosiclare, nitre.

Jo Davies Co.-At Galena, galenite, calcite, pyrite, blende; at Marsden's diggings, galens ite! blende, cerussite, marcasite in stalactitic forms, pyrite.
Joliet. - Marble.
Quincy.-Calcite! pyrite.
Scales Mound.-Barite, pyrite.

## INDIANA.

Limestone Caverns; Corydon Caves, etc.-Epsom salt.
In most of the southwest counties, pyrite, iron sulphate, and feather alum; on Sugax Creek, pyrite and iron sulphate; in sandstone of Lloyd Co., near the Ohio, gypsum ; at the top of the blue limestone formation, brown spar, calcite.
Lawrence Co. - Spice Valle, kaolinite (=indianaite).

## MINNESOTA.

Nortil Shore of L. Superior) range of hills runnin.r nearly northeast and southwest, extending from Fond du Lac Superieure to the Kamanistiqueia River in Upper Canada). Scolecite, apophyllite, prehnite, stilbite, laumontite, heulandite, /harmotome, thomsonite, fluorite, barite, tourmuiine, epidote, hornblende, calcite, quartz crystals, pyrite, magnetite, steatite, blende, black oxyd of copper, malachite, native copper, chalcopyrite, amethystine quartz, ferruginous quartz, chalcedony, carnelicn, agate, drusy quartz, hyalite? fibrous quartz, jasper, prase (in the debris of the lake shore), dogtooth, spar, augite, native silver, spodumene ? chlorite; between Pigeon Point and Fond du Lac, near Baptism River, saponite (thalite) in anygdaloid.
Kettle River Trap Range.-Epidote, nail-head calcite, amethystine quartz, calcite, undetermined zeolites, saponite.
Stillwater.-Blende.
Falls of tie St. Croix.-Malachite, native copper, epidote, nail-head spar.
Rainy Lake.-Actinolite, tremolite, fibrous hornblende, garnet, pyrite, magnetite, steatite.

## WISCONSIN.

Big Bull Falls (near).-Bog iron.
Blue Mounds.-Cerussite.
Hazle Green.-Calcite.
Lac Du Flambeau R.-Garnet, cyanite.
Left Hand R. (near small tributary).-Malachite, chalcocite, native copper, red coppes ore, earthy malachite, epidote, chlorite? quartz crystals.
Linden.-Galenite, smithsonite, llydrozincite.
Mineral Point and vicinity.-Copper and lead ores, chrysocolla, azurite! chalcopyrite, malachite, galenite, cerussite, anglesite, blende, pyrite, barite, calcite, marcasite, smithsonite / (so-called "dry-bone").
Montreal River Portage.-Galenite in gneissoid granite.
Sank Co.-Hematite, malachite, chalcopyrite.
Silullsburg.-Galenite! blende, pyrite ; at Emmet's digging, galenite and pyrite.

## IOWA.

Du Buque Lead Mineis, and elsewhere.-Galenite! calcite, blende, black oxide of manganese; at Ewing's and Sherard's diggings, smithsonite, calamine; at Des Moines, quarts crystals, selenite; Makoqueta R., brown iron ore; near Durango, galenite.
Cedar River, a branch of the Des Moines.-S'elenite in crystals, in the bituninous shale of the coal measures; also elsewhere on the Des Moines, gypsum abundant; argillaceous iron ore, spathic iron ; copperas in crystals on the Des Moines, above the Mouth of Saap and elsewhere, pyrite, blende.
Fort Dudge.--Celestite.
Makoqueta.-Hematite.
New Galena.-Octahedral galenite, anglesite.

## MISSOURI.

## Birmingham. -Limonite.

Granby.-Sphalerite, galenite, calamine, greenockite, as a coating on sphalérite.
Jefferson Co., at Valle's diggings.-Galenite, cerussite, anglesite, calamine, chalcopy rite malachite, azurite, witherite.
Mine \& Burton.-Galenite, cerussite, anglesite. barite, calcite.
Deep diggings. - Malachite, cerussite in crystals and manganese ore.
Madison Co.-Wolframite.
Mine La Motte.-Galenite! malachite, eartly cobalt and nickel, bog manganese, sulphide of irou and nickel, cerussite, caledonite, plumbogummite, wolframite, siegenite, smaltite, aragonite.

St. Lours.-Millerite, calcite, dolomite, earthy barite, fluorite.
St. Francis River.-Wolframite.
Perry's Diggings, and elsewhere--Galenite, eto.
Forty miles west of the Mississippi and ninety south of St. Louis, the iron ;mountains, specular iron, limonite; 10 m . east of Ironton, wolframite, tungstite.

## ARKANSAS.

Batesville.-In bed of White R., some miles above Batesville, gold.
Green Co.-Near Gainesville, lignite.
Hot Springs Co.-At Hot Springs, wavellite, thuringite ; Magnet Cove, brookite! schorlomite, elcoolite, magnetite, quartz, green coccolite, garnet. apatite, perofskite (hydrotitanite), rutile, ripidolite, thomsonite (ozarkite), microcline, ægirite.

Independence Co.-Lafferay Creek, psilomelane.
Lawrence Co.-Hoppe, Bath, and Koch mines, smithsonite, dolomite, galenite; nitre.
MARION Co.-Wood's mine, smithsonite, hydrozincite (marionite), galenite; Poke bayou, braunite?

OuAchita Springs.-Quartz? whetstones.
Pulaski Co.-Kellogg mine, 10 m . north of Little Rock, tetrahedrite, tennartite, nacrite galenite, blende, quartz.

## CALIFORNIA.

The principal gold mines of California are in Tulare, Fresno, Mariposa, Tuolumne, Calavesas, El Dorado, Placer, Nevada, Yuba, Sierra, Butte, Plumas, Shasta, Siskiyou, and Del Norte counties, although gold is found in almost every county of the State. The gold occurs in quartz, associated with sulphides of iron, copper, zinc, and lead; in Calaveras and Tuolomne counties, at the Mellones, Stanislaus, Golden Rule, and Rawhide mines, associated with tellurides of gold and silver; it is also largely obtained from placer diggings, and further it is found in beach washings in Del Norte and Klamath counties.

The copper mines are principally at or near Copperopolis, in Calveras county; near Genesee Valley, in Plumas county; near Low Divide, in Del Norte county; on the north fork of Smith's River ; at Soledad, in Los Angeles county.

The mercury mines are at or near New Almaden and North Almaden, in Santa Clara county; at New Idria and San Carlos, Monterey county; in San Luis Obispo county; at Pioneer mine, and other localities in Lake county ; in Santa Barbara county.

ALPINE Co.-Morning Star mine, enargite, stephanite, polybasite, barite, quartz, pyrite, tetrahedite.

AMADOR Co.-At Volcano, chalcedony, hyalite.
Alameda Co.-Diabłlo Range, magnesite.
Butte Co.-Chernkee Flat, diamond, platinum, iridosmine.
Calaveras Co. - Copperopolis, chalcopyrite malachite, azurite, serpentine, picrolite, native copper, near Murphy's, jasper, opal ; albite, with gold and pyrite ; Mellones mine, calaveritis, petzite.

Contra-Costa Co.-San Antonio, chalcedony.
Del Norte Co.-Cresoent City, agate, carnelian; Low Divide, chalcopyrite, bornite, malachite; on the coast, iridosmine, platinure.

El Dorado Co.-Pilot Hill, chalcopyrito, near Georgetown, hessite, from placer dig. gings; Roger's Claim, Hope Valley, grossular garnet, in copper ore; Colona, chromite: Epanish Dry Diggings, gold; Granite Creek, roscoelite, gold.

Eresno' Co.-Chowchillas, andalusite.
Humboldt Co.-Cryptomorphite.
In'ॄo Co.-Ingo district, galenite, cerussite, anglesite, barite, atacamite, cancite, glossular sarnet!

Lake Co.-Borax Lake, borax!' sassolite, glauberite ; Pioneer mine, cinnabar, native mercury, selenide of mercury; near the Geysers, sulphur, hyalite; Redington mine, metacinnabarite.

Los Angeles Co. - Near Santa Anna River, anhydrite; Williams Pass, chalcedony; Soledad mines, chalcopyrite, garnet, gypsum; Mountain Meadows, garnet, in copper ore.

Mariposa Co. - Chalcopyrite, itacolumyte; Centreville, cinnabar; Pine Tree Mine, tetra-
hedrite; Burns Creek, limonite; Geyer Gulch, pyrophyllite ; La Victoria mine, azurite! near Coulterville, cinnabar, gold.

Mono Co--Partzite.
Monterey Co.-Alisal Mine, arsenic; near Paneches, chalcedony; New Idria mine, cinnabar; near New Idria, chromite, zaratite, chrome garnet ; near Pacheco's Pass, stibnite.

Nevada Co.-Grass Valley, gold! in quartz veins, with pyrite, chalcopyrite, blende, arsenopyrite, galenite, quartz, biotite; near Truckee Pass. gypsum ; Excelsior Mine, molybdenite, with molybdenite and gold ; Sweet Land, pyrolusite.

Placer Cu.-Miner's Ravine, epidote! with quartz, gold.
Plumas Co.-Genesee Valley, chalcopyrite ; Hope mines, bornite, sulphur.
Santa Barbara Co.--San Amedio Cañon, stibnite, asphaltum, bitumen, maltha, petroleum, cinnabar, iodide of mercury; Santa Clara River, sulphur.

San Diego Co.-Carisso Creek, gypsum ; San Isabel, tourmaline, orthoclase, garnet.
San Francisco Co.-Red Island, pyrolusite and manganese ores.
Santa Clara Co.-New Almaden, cinnabar, calcite, aragonite, serpentine, chrysolite, quartz, aragotite; North Almaden, chromite; Mt. Diablo Range, magnesite, datolite, with vesuvianite and garnet.

San Luis Obispo Co.-Asphaltum, cinnabar, native mercury.
San Bernardino Co.-Colorado River, agate, trona; Temescal, cassiterite; Russ District, galenite, cerussite; Francis mine, cerargyrite.

Shasta Co.-Near Shasta City, hematite, in large masses.
Siskiyou Co.-Surprise Valley, selenite, in large slabs.
Sonoma Co.-Actinolite, garnets.
Tulare Co.-Near Visalia, magnesite, asphaltum.
Tuolimne Co.-Tourmaline, tremolite; Sonora, graphite; York Tent, chromite; Golden Rule mine, petzite, calaverite, altaite, hessite, magnesite, tetrahedrite, golả; Whiskey Hill gold!
Trinity Co.-Cassiterite, a single specimen found.

## LOWER CALIFORNIA.

La Paz.-Cuproscheelite. Loretro.-Natrolite, siderite, selenite.

## UTAF.

Beaver Co.-Bismuthinite, bismite, bismutite.
Tintic District.-At the Shoebridge mine, the Dragon mine, and the Mammoth velu, enargite with pyrite.
Box Elder Co.-Empire mine, wulfenite!
In the Wahsatch and Oquirrh mountains there are extensive mines, especially of ores of lead rich in silver. At the Emma mine occur galenite, cervantite, cerussite, wulfenite, azurite, malachite, calamine, anglesite, linarite, sphalerite, pyrite, argentite, stephanite, etc. At the Lucky Boy mine, Butterfield Cañon., orpiment, realgar.

One hundred and twenty miles south-west of Salt Lake City, topaz has been found in colorless cry stals.

## NEVADA.

Carson Valley.-Chrysolite.
Ohurchill Co.-Near Ragtown, gay-lussite, trona, common salt.
Comstock Lode.-Gold, native silver, argentite, stephanite, polybasite, pyrargyrite, prous tite, tetrahedrite, cerargyrite, pyrite, chalcopyrite, galenite, blende, pyromorphite, allemov Lite, arsenolite, quarts, calvite, gypsum, cerussite, cuprite, wulfenite, amethyst, küstelita.

Rsmeralda Co.-Alum, 12 m . north of Silver Creek ; at Aurora, fluorite, stibnite; nean Monu Lake, native copper and cuprite, obsidian; Columbus district, ulexite; Walker Lake, gypsum, hematite ; Silver Peak, salt, saltpetre, sulphur, silver ores.

Humboldt District.-Sheba mine, nutive silver, jamesonite, stibnite, tetrahedrite, prous tite, blende, cerussite, calcite, bournonite, pyrite, galenite, malachite, xanthocone (?)

Mammoth Distirict.-Orthoclase, turquois, hübnerite, scheelite.
lleese River District.-Native silver, proustite, pyrargyrite, stephanite, blende, polybasite, rhodochrosite. embolite, tetr ahedrite! cerargyrite, embolite.

San Antonia.-Belmont mine, stetefeldtite.
Six Mile Cã̃on.-Néenite.
Ormsby Co.--W. of Carson, epidote.
Storey Co.-Alum, natrolite, scolezite.

## ARIZONA.

On and near the Colorado, gold, silver, and copper mines; at Bill Williams' Fork, chrysocolla, malachite, atacamite, brochantite; Dayton Lode, gold, fluorite, cerargyrite; Skinner Lode, octahedral fluorite; at various places in the southern part of the territory, silver and copper mines; Heintzelmann mine, stromeyerite, chalcocite, tetrahedrite, atacamite. Montgomery mine, Harsayampa Dist., tetradymite. Whitneyite, in Southern Arizona.

## OREGON.

Gold is obtained from beach washings on the southern coast; quartz mines and placer mines in the Josephine district; also on the Powder, Burnt, and John Day's rivers, and other places in eastern Oregon; platinum, iridosmine, laurite, on the Rogue River, at Port Oxford, and Cape Blanco. In Curry Co., priceite.

## IDAHO.

In the Owyhee, Boise, and Flint districts, gnld, also extensive silver mines; Poor Man Lode, cerargyrite! proustite, pyrargyrite! native silver, gold, pyromorphite, quartz, malachive polybasite; on Jordan Creek, stream tin; Rising Star mine, stephanite, argentite, pyrargy rite.

## MONTANA.

Many mines of gold, etc., west of the Missouri R. Higmland District.-Tetradymite Silver Star Dist.-Psittacinite.

In the Yellowstone Park, in Montana and Wyoming Territories.-Geyserite.-Amethyst chalcedony, quartz crystals, quartz on calcite, etc.

## COLORADO.*

The principal gold mines of Colorado are in Boulder, Gilpin, Clear Creek, and Jefferson Cos., on a line of country a few miles W. of Denver, extending from Long's Peak to Pike's Peak. A large portion of the gold is associated with veins of pyrite and chalcopyrite; silver and lead mines are at and near Georgetown, Clear Creek Co., and to the westward in Summit Co., on Snake and Swan rivers.

At the GEORGETOWN mines are found:-native silver, pyrargyrite, argentite, tetrahedrite, pyromorphite, galenite, sphalerite, azurite, aragonite, barite, fluorite, mica.

Trail Crefk. - Garnet, epidote, hornblende, chlorite; at the Freeland Lode, tetrahedrite, tennantite, anglesite, caledonite, cerussite, tenorite, siderite, azurite, minium; at the Champion Lode, tinorite, azurite, chrysocolla, malachite; at the Gold Belt Lode, vivianite; at the Kelly Loile, tenorite; at the Coyote Lode, malachite, cyanotrichite.

Near Black Hawk.-At Willis Gulch, enargite, fluorite, pyrite; at the Gilpin County Lode, cerargyrite ; on Gregory Hill, feldspar; North Clear Creek, lievrite.-Gulcnite!

[^63]Bear Creek.-Fluorite, beryl; near the Malachite Lode, malachite, cuprite, vesurianite topazolite ; Liberty Lode, chalcocite.

Snake River.-Penn District, embolite; at several lodes, pyrargyrite, native silver, azurite.
Russelil District.-Delaware Lode, chalcopyrite, crystallized galenite.-Epidote, pyrite.
Virginia Cañon.-Epidote, fluorite; at the Crystal Lode, native silver, spinei.
Sugar Loaf District.-Chalcocite, pyrrhotite, garnet (manganesian).
Central City.-Garnet, tenorite ; at Leavitt Lode, molybdenite; on Gunnell Hill, mag netite; at the Pleasantview mine, cerussite.

Golden City.-Aragonite.
Bergen's Rancie.-Garnet, actinolite, calcite.
Boulder Co., Red Cloud Mine.-Native tellurium, altaite, hessite (petzite), sylvanite: calaverite, schirmerite.

Lake City, at the Hotchkiss Lode.-Petzite, calaverite (?), etc.
Pike's Peak, on Elk Creek.-Amazonstone! ! smoky quartz! aventurine feldspar, ame thyst, albite, fluorite, hematite, anhydrite (rare), columbite.

## CANADA.

## canada east.

Abercrombie. - Labradorite.
Bay St. Padl.-Mennaccanite! apatite, allanite, rutile (or brookite?)
Aubert. - Gold, iridosmine, platinum.
Bolton. - Chromite, magnesite, serpentine, picrolite, steatite, bitter spar, wad.
Boucherville.-Augite in trap.
Brome.-Magnetite, chalcopyrite, sphene, menaccanite, phyllite, sodalite, cancrinite, galenite, chloritoid.

Cifmbly.-Analcite, chabazite and calcite in trachyte, menaccanito.
Chateau Ricier.-Labradorite, hypersthene, andesite.
Daillebout.-Blue spinel with clintonite.
Grenville.-Wollastonite, sphene, vesuvianite, calcite, pyroxene, steatite (rensselaerite), garnet (cinnamon-stone), zircon, graphite, scapolite.
llam.-Chromite in serpentine, diallage, antimony! senarmontite! kermesite, valentinite, stibnite.

Inverness. - Variegated copper.
Lake St. Francis.-Andalusite in mica slate.
Landsdown.--Barite.
Leeds.-Dolomite, chalcopyrite, gold, chloritoid.
Mille Isles.-Labradorite! menaccanite, hypersthene, andesite, zircon.
Montreal.-Culcite, rugite, sphene in trap, chrysolite, natrolite, dawsonite.
Morin.-Sphene, apatite, labradorite.
Orford.-White garnet, chrome garnet, millerite, serpentine.
Ottawa.-Pyroxene.
Polton.-Chromite, steatite, serpentine, amianthus.
Rougemont.-Augite in trap.
Silerbrook.-At Suffield mine, albite! native silver, argentite, chalcopyrite, blende.
St. armand.-Micaceous iron ore with quartz, epidote.
St. François Beauce.-Gold, platinum, iridosmine, menaccanite, magnetite, serpentine, chromite, soapstone, barite.

St. Jerome.-Sphene, apatite, chondrodite, phlogopite, tourmaline, zircon, molybdenite, pyrrhotite.

St. Norbert. -Amethyst in greenstone.
Stukeley.-Serpentine, verd-antique! schiller spar.
Sutton.-Magnetite in fine crystals, hematite, rutile, dolomite, magnesite, chromiferous tclle, bitter spar, steatite.

UPTON.-Chalcopyrite, malachite, calcite.
Vaudreurl.-Limonite, vivianite.
Yamaska. - Sphene in trap.

## Arnprior.-Calcite.

## CANADA WEST.

BALSAM Lake. - Molybdenite, scapolite, quartz, pyroxene, pyrite.
Brantrord. - Sulphuric acid spring (4:2 parts of pure sulphuric acid in 1000).
BATIURST.-Barite, black tourmaline, perthite (orthoclase), peristerite (albite), bytowntt, pyroxene, wilsonite, scapolite, apatite, titanite.

## Brockville.-Pyrite.

Brome.-Magnetite.
Bruce Mines.-Culcite, dolomite, quartz, chalcopyrite.
Burgess.-Pyroxene, albite, mica, sapphive, sphene, chalcopyrite, xpatite, biack spintl: spodumene (in a boulder), serpentine, biotite.

Bytown. - Calcite, bytownite, chondrodite, spinel.
Cape Ipperwash, Lake Huron.-Oxalite in shales.
Clarendon. - Vesuvianite.
Dalhousie.-Hornblende, dolomite.
Drummund. - Labradorite.
Elizabethtown. - Pyrrhotite, pyrite, calcite, magnetite, talc, phlogopite, siderite, apatite, cacoxenite.

Elmsey.-Pyroxene, sphene, feldspar, tourmaline, apatite, biotite, zircon, reu spincl, chondrodite.

Fitzroy.-Amber, brown tourmaline, in quartz.
Geetineau River, Blasdell's Mills.-Calcite, apatite, tourmaline, hornblende, pyroxene.
Grand Calumet Island.- Apatite, phlogopite! pyroxene! sphene, vesuvianite!! serpen. tine, tremolite, scapolite, brown and black tourmaline! pyrite, loganite.

High Falls of the Madawaska.--Pyroxene! hornblende.
Holl. - Magnetite, garnet, graphite.
HUNTERSTOWN: - Scapolite, spliene, vesuvianite, garnet, brovon tourmaline!
Huntington.-Calcite!
Inniskillen.-Petroleum.
Kingston. - Celestite.
Lac des Chats, Island Portage. - Brown tourmaline! pyrite, calcite, quartz.
LANARK. - Raphilite (hornblende), serpentine, asbestus.
Landstown. - Barite! vein 27 in . wide, and fine crystals.
Madoc. - Magnetite.
Mamora. - Magnetite, chalcolite, garnet, epsomite, specular iron.
Maimanse. - Pitchblende (coracite).
McNab.--Hematite, barite.
Michipicoten Island, Lake Superior. - Domeykite, niccolite, genthitc.
Newborougr. - Chondrodite, graphite.
Packinilam.-Hornblende.
Pertir. - Apatite in large beds, phlogopite.
Soutri Crosby. - Chondrodite in limestone, magnetite.
ST. ADELE.-Chondrodite in limestone.
St. Ignace Island.-Calcite, native copper.
Sydenham. - Celestite.
Terrace Cove, Lake Superior.-Molybdenite.
Wallace Mine, Lake Huron.-Hematite, nickel ore, nickel vitriol.

## NEW BRUNSWICK.*

Albert Co.-Hopewell, gypsum ; Albert mines, coal (albertite); Shepody Mountain nlunite in clay, calcite, iron pyrites, manganite, psilomelane, pyrolusite.

Carleton Co.-Woodstock, chalcopyrite, hematite, limonite, wad.
Charlotte Co. - Campobello, at Welchpool, blende, chalcopyrite, bornite, galenite, pyrite; at head of Harbor de Lute, galenite ; Deer Island, on west side, calcite, magnetite, quartz crystals; Digdignash River on west side of entrance, calcite! (in conglomerate), chalcedony; at Rolling Dam, graphite; Grandmanan, between Northern Head and Dark Harbor, agate, amcthyst, apophyllite, calcite, hematite, heulandite, jasper, magnetite, natrolite, stilbite; at Whale Cove, calcite! heulandite, laumontite, stilbite, semi-opal! Wagaguadavic River, at entrance, azurite, chalcopyrite in veins, malachite.

Gloucester Co.-Tete-a-Gouche River, eight miles from Bathurst, chalcopyrite (mined), oxide of mangan bse! ! formerly mined.
Kings Co.-Sussex, near Cloat's mills, on road to Belleisle, argentiferous galenite; one mile north of Baxter's Inn, specular iron in crystals, limonite; on Capt. McCready's farm, selenite!!
Restigovcire Co.-Belledune Point, calcite! serpentine, verd-antique; Dalhousie, agate, carnelian.

[^64]Sannt John Co. - Black River, on coast, calcite, chlorite, chalowyrite, hematite! Brandy Brook, epidote, hornblende, quartz crystals; Carleton, near Falls, calcite; Chance Harbor, calcite in quartz veins, chlorite in argillaceous and talcose slate; Little Dipper Harbor, on west side, in greenstone, amethyst, barite, quartz crystals; Moosepath, feldspar, hornblende, muscovite, black tourmaline; Musquash, on east side harbor, copperas, graphite, pyrite ; at Shannon's, chrysolite, serpentine ; east side of Musquash, quartz crystals! ; Portland, at the F'alls, graphite ; at Fort Howe Hill, calcite, graphite ; Crow's Nest, asbestus, chrysolite. magnetite, scrpentine, steatite; Lily Lake, white augite? chrysolite, graphite, serpentine steatite, talc ; How's Road, two miles out, epidote (in syenite), steatite in limestone, tremo lite; Drury's Cove, graphite, pyrite, pyrallolite? indurated talc ; Quaco, at Lighthouse Point, large bed oxyd of manganese; Sheldon's Point, actinolite, asbestus, calcite, epidote, malachite, specular iron; Cape Spenser, asbestus, calcite, chlorite, specular iron (in crystals); Westbeach, at east end, on Evans' farm, chlorite, talc, quartz crystals; half a mile west, chlorite, chalcopyrite, magnesite (vein), magnetite ; Point Wolf and Salmon River, asbestus, chlorite, chrysocolla, chalcopyrite, bornite, pyrite.

Victoria Co.-Tabique River, agate, carnelian, jasper; at mouth, south side, galenite ; at mouth of Wapskanegan, gypsum, salt spring ; three miles above, stalactites (abundant); Quisabis River, blue phosphate of iron, in clay.

Westmoreland Co.-Bellevue, pyrite; Dorcester, on Taylor's farm, cannel coal ; clay ironstone ; on Ayres's farm, asphaltum, petroleum spring; Grandlance, apatite, selenite (in large crystals); Memramcook, coal (albertite); Shediac, four miles up Scadoue River, coal.

York Co.-Near Fredericton, stibnite, jamesonite, berthierite; Pokiock River, stibnite, tin pyrites? in grauite (rare).

## NOVA SCOTIA.

Anvapolis Co.-Chute's Cove, apoyhyllite, natrolite; Gates' Monntain, amalcite, magnetite, mesolite! natrolite, stilbite; Martial's Cove, analcite! chabazite, heulandite; Moose River, beds of magnetite; Nictau River, at the Falls, bed of hematite ; Paradise River, black tourmaline, smoky quartz!!; Port George, faröelite, laumontite, mesolite, stilbite ; east of Port George, on coast, apophyllite containing gyrolite ; Peter's Point, west side of Stonock's Brook, apophyllite! calcite, heulandite, laumontite! (abundant), native copper, stilbite ; St. Croix Cove, chabazite, heulandite.

Colchester Co.-Five Islands, East River, barite! calcite, dolomite (ankerite), hematite, chalcopyrite; Indian Roint, malachite, magnetite, red copper, tetrahedrite; Pinnacle Islands, analcite, calcite, chabazite! natrolite, siliceous sinter; Londonderry, on branch of Great Village River, barite, ankerite, hematite, limonite, magnetite; Cook's Brook, ankerite, hematite ; Martin's Brook, hematite, limonite; at Folly River, below Falls, ankerite, pyrite ; on high land, east of river, ankerite, hematite, limonite ; on Archibald's land, ankerite, barite, hematite; Salmon River, south branch of, chalcopyrite, hematite; Shubenacadie River, anhydrite, calcite, barite, hernatite, oxide of manganese; at the Canal, pyrite; Stewiacke River, barite (in limestone).

Cumberland Co.-Cape Chiegnecto, barite ; Cape D`Or, analcite, apophyllite!! chabazite, faröelite, laumontite, mesolite, malachite, natrolite, native copper, obsidian, red copper (rare), vivianite (rare) ; Horse-shoe Cove, east side of Cape D'Or, analcite, calcite, stilbite ; Isle Haute, south side, analcite, apophyllite!! calcite, heulandite!! natrolite, mesolite, stilbite! Joggins, coal, hematite, limonite; malachite and tetrahedrite at Seaman's Brook; Partridge Island, analcite, apophyllite! (rare), amethyst! agate, apatite (rare), calcite!! chabazite (acadialite), chalcedony, cat's-eye (rare), gypsum, hematite, heulandite! magnetite, stillite!!; Swan's Creek, west side, near the Point, calcite, gypsum, heulandite, pyrite east side, at Wasson's Bluff and vicinity, analcite!! apoplyllite! (rare), calcite, chabazite!! (acadialite), gypsum, heulandite!! natrolite! siliceous sinter; Two Islands, moss agate, analcite, calcite, chabazite, heulandite; McKay's Head, analcite, calcite, heulandite, siliceous sinter!

Digby Co.-Brier Island, native copper, in trap; Digby Neck, Sandy Cove and vicinity, agate, amethyst, calcite, chabazite, hematite! laumontite (abundant), magnetite, stillite, quartz crystals; Gulliver's Hole. magnetite, stilbite! ; Mink Cove, amethyst, chabazite ! quartz crystals; Nichols Mountain, south side, amethyst, magnetite!; Williams Brook, prar source, chabazite (green), heulandite, stilbite, quartz crystal.

Gyysboro' Co.-Cape Canseau, andulusite.
Halifax Co.-Gay's river, galenite in limestone; southwest of Halifax, garnet, staurolite, tourmaline: Tangier, gold! in quartz veins in clay slate, associated with auriferous pyrites, galenite, hematite, mispickel, and magnetite; gold has also been found in the same forma tion, at Country Harbor, Fort Clarence, Isaac's Harbor, Indian Harbor, Laidlow's farm Lawrencetown, Sherbrooke, Salmon River, Wine Cove, and other places.

Hants Co. - Cheverie, oxide of manganese (in limestone) ; Petite River, gypsum, oxile of manganese ; Windsor, calcite, cryptomorphite (boronatrocalcite), howlite, glauber sall. The last three minerals are found in beds of gynsum.

Kings Co.-Black Rock, centrallassite, cerinite ; cyanolite ; a few miles east of Black Rock, prehnite ! stillite! ; Cape Blomidon, on the coast between the cape and Cape Split, the following minerals occur in many places (some of the best localities are nearly opposite Cape Sharpi): analcite!! agate, amethyst! apophyllite! calcite, chalcedony, chabazite, gmelinite (ledererite), hematite, heulandite! laumontite, magnetite, malachite, mesolite, native copper (rare), natrolite! psilomelane, stilbite! thomsonite, faröelite, quartz; North Mountains, amethyst, bloodstone (rare), ferruginous quartz, mesolite (in soil); Long Point, five miles west of Black Rock, heulandite, luumontite!! stilbite!! ; Morden, apophyllite, mordenite; Scot's Bay, agate, amethyst, chalcedony, mesolite, natrolite; Woodworth's Cove, a few miles west of Scot's Bay, agate! chalcedony! jasper.

Lunin $b u r g$ Co.-Chester, Gold River, gold in quartz, pyrite, mispickel ; Cape la Have, pyrite; The "Ovens," gold, pyrite, arsenopyrite; Petite River. gold in slate.

Pictou Co.-Pictou, jet, oxide of manganese, limonite ; at Roder's Hill, six miles west of Pictou, barite ; on Carribou River, gray copper and malachite in lignite; at Albiou mines, coal, limonite ; East River, limonite.

Queens Co.-Westfield, gold in quartz, pyrite, arsenopyrite; Five Rivers, near Big Fall, gold in quartz, pyrite, arsenopyrite, limonite.

Ricimond Co.-West of Plaister Cove, barite and calcite in sandstone; nearer the Cove, calcite, fluorite (blue), siderite.
Siflburne Co.-Shelburne, near mouth of harbor, garnets (in gneiss); near the town, rose quartz ; at Jordan and Sable River, staurolite (abundant), schiller spar.

Sydney Co.-Hills east of Lochaber Lake, pyrite, chalcopyrite, sideride, hematite; Morristown, epidote in trap, gypsum.
Yarnouth Co.-Cream Pot, above Cranberry Hill, gold in quartz, pyrite; Cat Rock, Fouchu Point, asbestus, calcite.

## NEWFOUNDLAND.

Antony's Island.-Pyrite.
Catalina Harbor.-On the shore, pyrite!
Chalky Hill. - Feldspar.
Copper Island, one of the Wadham group.-Chalcopyrite.
Conception Bay.-On the shore south of Brigus, bornite and gray copper in trap.
Bay of Islands.-Southern shore, pyrite in slate.
Lawn.-Galenite, cerargyrite, proustite, argentite.
Placentia Bay.-AtLa Manche, two miles eastward of Little Southern Harbor, g rlenite ${ }^{\text {s }}$; on the opposite side of the isthmus from Placentia Bay, barite, in a large vein, occasions.ly accompanied by chalcopyrite.
Sioal Bay.-South of St. Johu's, chalcopyrite.
Trinity Bay.-Western extremity, barite.
Harbor Great St. Lawrence.-West side, fluo.ije, galenite.

## APPENDIX D.

## SUPPLEMENTARY CATALOGUE OF AMERICAN LOCALITIES OF MINERALS.

MAINE.<br>Norway.-Triphylite (lithiophilite), chrysoberyl, cookeite. Paris.-Columbite, mica, triphylite. Parsonfield.-Labradorite, crystallized. Peru.-Triphylite (crystallized), columbite, beryl, spodumene. Stoneiram.-Triplite, columbite, topaz, curved mica.

## NEW HAMPSHIRE.

Bartlett.-At the iron mine, danalite.

## MASSACHUSETTS.

Deerfield.-In diabase, datolite, stilbite, chabazite, prehnite, heulandite, natrolite, analcite, calcite, fluorite, albite, epidote, axinite, tourmaline, diabantite, saponite, chlorophæite, kaolin, pyrite, malachite, limonite, wad.

Rockport.-Fergusonite.

## CONNECTICUT.

Branchville.-In a large vein of pegmatite in gneiss, mica (curved concentric), microcline, albite (also crystallized), quartz (inclosing liquid $\mathrm{CO}_{2}$ ), spodumene and various alteration products (eucryptite, cymatolite, killinite, etc.), columbite, apatite (also manganapatite), amblygonite, lithiophilite, eosphorite, triploidite, dickinsonite, reddingite, fairfieldite, fillowite, rhodochrosite, uraninite (crystals), cyrolite, microlite, uranium phosphates, chabazite, stilbite, heulandite and other species.

Litchfield.-Staurolite in mica schist.
New Haven. - At Mill Rock, contact surface of trap and sandstone, garnet (topazolite); at East Rock, on columnar surfaces of trap, garnet (melanite), magnetite, pyroxene, apatite, calcite.

Portland.-At Pelton's feldspar quarry, monazite.

## NEW YORK.

## CLinton Co.-Plattsburg, nugget of platinum in drift.

ESSEX CO.-Port Henry, black tourmaline enclosing orthoclase; Champlain iron region, uranothorite.

ST. LAWRENCE CO.-DeKalb, white tourmaline.
Pictairn.--Titanite.
Russell.-In veins in a granitic rock, danburite with pyroxene, titanite, black mica.

## NEW JERSEY.

> Bergen.-Hayesine.
> Franklin Furnace and Sterling.-Chalcophanite, hetærolite, pyrochroite.

## PENNSYLVANIA.

BEDFORD CO. -Bridgeport, barite.
BERKS CO.-Jones's mine, aurichalcite, melaconite, byssolite.
BUCKS CO.-Phenixville, ankerite.
Bridgewater Station.-Titanite.
CHESTER CO.-Yellow Springs, allanite.
DELAWARE CO.-Waterville, near Chester, and Upland, chabazite.
Mineral Hill, columbite.
Leiperville, garnet, zoisite, heulandite, leidyite.
FRANKLIN CO. - Lancaster Station, barite.
HUNTINGTON CO.-Broad Top Mountain, barite.
LEHIGH CO.-Shimerville, corundum.
LUZERNE CO.-Scranton, under a peat-bed, phytocollite (dopplerite).
Drifton, pyrophyllite.
MIFFLIN CO.-Strontianite.
MONTGOMERY CO.--Upper Salford mine, azurite.
NORTHAMPTON CO.-BETHLEHEM, axinite.
PHILADELPHIA CO.-Germantown, fahlunite.
SCHUYLKILL CO., near Mahanoy City, pyrophyllite, alunogen, copiapite, in coal mines.

## DELAW ARE.

Dixon's Quarry.-Columbite.
Newark.-Quartz crystals, doubly terminated, loose in soil.

## VIRGINIA.

AMELIA CO.-From a granite vein (mica mine) in gneiss near Amelia Court House, mica in large sheets, quartz, orthoclase, microlite, monazite, columbite, orthite, heivite with topazolite, beryl, fluorite, amethyst, apatite (rare).
AMHERST CO.-From a feldspar vein in a gneissoid rock on the northwest slope of Little Friar Mt., allanite, sipylite, magnetite, zircon.
ROCKBRIDGE CO.-Underlying limonite, dufrenite in an irregular bed ten inches deep, strengite in cavities in dufrenite.

WYTHE CO.-Austin mine, aragonite (7 p. c. $\mathrm{PbCO}_{3}$ ).

## NORTH CAROLINA.*

Alexander Co.-Near Stony Point, in narrow veins or pockets in a gneissoid rock (in part also loose in overlying soil), spodumene (hiddenite), beryl (emerald), rutile, monazite, allanite, quartz.

At White Plains, quartz crystals, spodumene (hiddenite), beryl, rutile, scorodite, columbite, tourmaline.

At Milholland's mill, rutile, monazite, muscovite, quartz.
Burke Co.-In the auriferous gravels at Brindletown, octahedrite (transpareni), brookite, zircon, fergusonite, monazite, xenotime (compounded with zircon), garnet, tourmaline, magnetite and other species.

Mitchell Co.-At the mica mines, muscovite in large quantities, orthoclase, albite, samarskite, Jcolumbite, hatchettolite, rogersite, fergusonite, monazite, uraninite, gummite, phosphuranylite, uranotile, allanite, beryl, zoisite, garnet, menaccanite.

Yancey Co.-At the Ray mica mine, muscovite, tantalite (columbite), monazite, beryl, garnet, zircon, rutile, etc.

At Hampton's, chromite, epidote, enstatite, tremolite, chrysolite, serpentine, talc, magnesite, etc.

## ALABAMA.

COOSA CO.-Cassiterite, tantalite.

[^65]
## MICHIGAN.

Negaunee.-Manganite, göthite, hematite, barite, kaolinite.
Grand Marais.-Thomsonite (lintonite).

## MISSOURI.*

ADAIR CO.-Göthite with calcite in concretionary masses of clay iron-stone.
BARTON CO.-McCarrow's coal bank, pickeringite, as a white efflorescence on sandy shales of coal measures.

BENTON CO.-Limonite.
BOLLINGER CO.-Limonite, bog manganese, psilomelane.
CALLAWAY CO.-Hematite, clay iron ore.
CHARITON CO-Selenite.
COLE CO - Barite. At the Eureka mines, galenite, smithsonite.
COOPER CO.-Collins mine, malachite, azurite, chalcopyrite, smithsonite, galenite sphalerite, limonite.

CRAWFORD CO.-Scotia iron banks, hematite, quartz, jasper, amethyst, göthite, malachite.

DADE CO.-Smithsonite.
DENT CO.-Simmon's Mountain, hematite.
FRANKLIN CO.-Cove mines, galenite, cerussite, anglesite, barite.
Mine-à-Burton, galenite, cerussite, anglesite.
Moselle, limonite.
Mount Hope mine, galenite, sphalerite, calamine, smithsonite.
Stanton Copper mines, native copper, chalcotrichite, malachite, azurite, chalcopyrite.
Virginia mines, galenite, anglesite, cerussite, minium.
IRON CO.- РiLot Knor, hematite, serpentine, magnetite, quartz, manganese ore.
JASPER CO.-Joplin mines, galenite, sphalerite, pyrite, marcasite, cerussite, bitumen.
Oronogo.-Galenite, sphalerite, cerussite, smithsonite, anglesite.
Webb City.-Galenite, sphalerite.
JEFFERSON CO.-Palmer mines, galenite, cerussite, plumbogummite.
Valle mines, galenite, cerussite, anglesite, calamine, smithsonite, hydrozincite, malachite, azurite.

MADISON CO.-Enistein silver mine, galenite, sphalerite, wolframite, pyrite, quartz, muscovite, actinolite, fluorite.

Mine-la-Motte.-Galenite, linnæite (siegenite), cerussite, anglesite, pyrrhotite, earthy cobalt, bog manganese, plumbogummite, chalcopyrite, annabergite.

In granites, porphyries, etc., quartz, agate, hornblende, asbestos, serpentine, chlorite, epidote, feldspar.

MONITEAU CO.-Sampson's coal mine, galenite and sphalerite in cannel coal.
MORGAN CO.-Buffalo mines, galenite.
Humes Hill, barite.
NEWTON CO.-Granby mines, galenite, cerussite, pyromorphite, calamine, greenochite. sphalerite, smithsonite, hydrozincite, buratite, dolomite, calcite.

PHELPS CO - Hematite, siderite, limonite, ankerite.
ST. FRANCOIS C'O.-Iron mountain, hematite, apatite, tungstite, wolframite, magnetite, menaccanite.

ST. GENEVIEVE CO.-St. Genevieve copper mines, chalcopyrite, cuprite, malachite, azurite, covellite, chalcocite, bornite, melaconite, chalcanthite.

ST. LOUIS CO.-St. Louis.-In cavities in limestone, millerite, dolomite, calcite, fluorite, anhydite, gypsum, strontianite.

SALINE CO.-Halite in incrustations.
WAYNE CO.-Limonite.

## KANSAS.

BROWN CO.-Celestite.

## ARKANSAS.

Sevier Co.-Stibnite, stibiconite, bindheimite, jamesonite.
Hot Springs Co.-Rutile in eightlings, variscite.

[^66]
## COLORADO.

Boulder Co -Magnolia district (especially the Keystone, Mountain Lion and Smuggler mines), native tellurium, coloradoite, calaverite, tellurite, magnolite, ferrotellurite, sylvanite.

Chaffee Co.-Arrow mine, jarosite with turgite.
Custer Co.-Silver cliff, niccolite.
El Paso County.-Near Pike's Peak, arfvedsonite, astrophyllite, zircon; siderophyllite, topaz, phenacite, cryolite, thomsenolite (and other fluorides), tysonite, bastnäsite.

Gilpin Co.-Near Central City, pyrite in modified crystals, chalcopyrite often coated by tetrahedrite in parallel position, crystallized gold on pyrite.

Gunnison Co.-Near Gothic, smaltite.
Jefferson Co.-Near Golden, in basalt of T'able Mountain, chabazite, thomsonite, analcite, apophyllite, calcite, mesolite, laumontite.

La Plata Co.-Poughkeepsie Gulch, Alaska mine, alaskaite with tetrahcdite, chalcopyrite, barite.

Lake Co.-Leadville, cerussite carrying silver, anglesite, pyromorphite, sphalerite, calamine, minium, dechenite (?), rhodochrosite with galenite, chalcopyrite.
Golden Queen mine, scheelite with gold. Ute and Ule silver mine, stephanite, galenite, sphalerite, chalcocite.

Park Co.-Grant P. O., Baltic lode, beegerite. Hall Valley, ilesite.

## CALIFORNIA.

Inyo Co.-San Carlos, datolite with grossular garnet and vesuvianite.
Los Angeles Co.-Brea Ranch, vivianite in nodules with asphaltum.

## OREGON.

Douglas Co.-Cow Creek, Piney Mountain, considerable deposits of a hydrous nickel silicate, allied to garnierite.

Grant Co.-Canyon City, cinnabar with calcite.

## UTAH.

Iron Co.-Coyote District, orpiment and realgar in a thin bed in the horizontal sedimentary formations underlying lava.

Piute Co.-Marysvale, onofrite.
Salt Lake Co.--Butterfield Cañon, mallardite, lückite.
Wahsatch Range, head waters of Spanish Fork, ozocerite in considerable beds.

## NEVADA.

Elko Co.-Emma mine, chrysocolla; Blue Hill mine, azurite, malachite.
Lander Co.-Austin, polybasite, chalcopyrite, azurite, whitneyite.
Lincoln Co.-Halite, cerargyrite.
Nye Co.-Anglesite, stetefeldtite, azurite, cerussite, silver ore, cerargyrite.
White Pine Co.-Eberhardt mine, cerargyrite; Paymaster mine, freieslebenite.

## NEW MEXICO.*

Doña Ana Co.-Lake Valley, cerargyrite in the Sierra mines in large masses, rarely crystallized, associated with embolite, cerussite, galenite, vanadinite in small canary-yellow crystals, native silver, pyrolusite, manganite, fluorite, ankerite, apatite, chert. Victoria mine, 40 miles below Nutt, massive anglesite. Kingston, in Black Range; argentite in large masses.

Socorro Co.-Socorro Mt., 3 miles from town of Socorro, large veins of barite carrying cerargyrite, vanadiferous mimetite, vanadinite in barrel-shaped crystals resembling pyromorphite. Magdalena Mountains, 27 miles west of Socorro, cerussite in heavy veins with galenite, sphalerite, etc. Green and blue calamine on the Kelly location. Sophia mine, stromeyerite? Grafton, on a large quartz vein, I vanhoe mine, gold in black cerussite, chalcocite, bornite, malachite, azurite, chalcopyrite, cerargyrite, amethystine quartz. New Elk Mountain, 100 miles south of Socorro, cerussite carrying silver.

[^67]Grant Co.-Silver City, Bremen's mine, argentite, cerargyrite, argentite pseudomorph of mollusca, barite with cerargyrite, native silver in filagree and dendrites on slate; Santa Rita copper mines, native copper, tenorite. Mogollon and Burro mountains, Coony mining district, Dry Creek; in Mundo mine, melaconite; Silver Twigg mine, bornite, copper; Albatross mine, bornite, malachite; Cooney mine, chalcopyrite, azurite, bornite; Cliíton mine, native copper, cuprite, azurite, malachite, wulfenite. Georgetown, Naiad Queen mine, argentite pseudomorph of mollusca. cerargyrite, native silver in dendritic form on slate.

San Miguel Co.-Cerillos, Mt. Chalchuitl, turquoise in tuff. In the Cerillos district are numerous mineral veins, carrying silver lead and salts of lead, rarely wulfenite and vanadinite, azurite, malachite, sphalerite, etc.

## ARIZONA.

In the Silver District, Yuma Co., at the Hamburg, Princess and Red Cloud mines, in connection with quartz veins carrying argentiferous galena, fine ruby-red vanadinite, red wulfenite, massive anglesite. Silent District, Black Rock mine, vanadinite. At the Castle Dome mines, vanadinite, mimetite, wulfenite, cerussite, galenite, fluorite. Also wulfenite at the Melissa mine and Rover mine.

In the Vulture District (also called White Picacho District), Yavapai and Maricopa Cos., numerous veins of gold-bearing quartz, carrying lead. Vulture mine, cryst. gold, jarosite, wulfenite. Hunter's Rest mine, gold in tourmaline rock. Farley's Collateral mine, and the Phenix mine, 20 miles north-east of Vulture, yellow vanadinite vith calcite, wulfenite, cerussite, descloizite (?), volhorthite (?) crocoite, vauquelinite, phœenicochroite. Montezuma mine, vanadinite, cerussite. Sante Domingo mine, mimetite, argentite. Silver Star mine, native silver, cerussite, argentite, crocoite, vanadinite. Tiger mine, native silver, cerargyrite. Tip Top mine, native silver, sphalerite, argentite, pyrargyrite.

From the Rio Verde, Maricopa Co., thenardite in large deposits.
Mohave Co.-Moss lode, gold in crystalline plates; fluorite a frequent gangue material.
Pinal Co.-Mule Pass, Bisbey, Copper Queen mine, native copper, copper oxide, malachite, azurite, calcite.

From the Silver King mine, Pioneer District, Pinal Co.-Fine crystallized native silver, argentite, sphalerite, pyrite. Stonewall Jackson mine, cryst. silver, argentite.

From the Bon Ton mines, Chase Creck, near Clifton, dioptase with cuprite and limonite.

## MONTANA.

Butte Co.-Butte City, Alice silver mine, rhorlonite, a common gangue of native silver and other silver ores, rhodochrosite. Same in Magna Charter mine. Parrot, Mountain, Bell, and other copper veins yield various copper salts and arsenical copper glance with silver.
"Original Butte mine," wurtzite with pyrite. Clear Grit mine, native silver, argentite, chalcopyrite, sphalerite, calcite, rhodochrosite. Colusa mine, chalcocite.

## ALASKA.

Ft. Wrangell at mouth of the Stickeen River, fine garnets in mica schist.

## CANADA-Province of Quebec.

Montreal.-Analcite, sodalite, nephelite (in nephelite-syenite).
Ottawa Co.-Veins carrying apatite and pyroxene in large quantities are common in Buckingham, Burgess, Templeton, and other townships; also calcite, quartz, amphibole, scapolite, garnet, tourmaline, titanite, zircon, orthoclase, phlogopite and other species.

Templeton, vesuvianite, garnet (cinnamonstone), pyroxene.
Hull, colorless garnets, vesuvianite, white pyroxene.
Wakefield, chrome garnet.

## CANADA-Province of Ontario.

Frontenac Co.-Scapolite, apatite.
Renfrew Co.-Eganville, large crystals of apatite, titanite, zircon (also twins), amphibole.

## NOVA SCOTIA.

Cumberland Co.-Alunogen.
Colchester Co.-New Annan, covellite.
Kivgs Co.-Black Rock, in trap with stilbite, ulexite, heulandite.

## CaNADA-Keewatin District.

Churchill River.-Lazulite.
Knee Lake.-Magnetite Island, magnetite.

## CANADA-British Columbia.

Cariboo Districtr.-Natiye gold, galenite.
On Frazer River.-Gold, argentiferous tetrahedrite, cerargyrite, cinnabar. North Thompson River, cyanite.

Howe Sound.-Bornite, chalcopyrite, molybdenite, mica.
Ominica District.-Gold, galenite, silver, silver amalgam.
Cassiar District.-Gold.
Texada Island.-Magnetite.
Queen Charlotte Islands.-Skincuttle Inlet, Harriet Harbor, magnetite, chalcopyrite.

## APPENDIX E.

## TABLES TO BE USED IN THE DETERMINATION OF MINERAL⿷.

## TABLE 1.

## Minerals arranged according to their Physical and Blowpipe Characters.

The following table is intended especially for use in instruction in Mineralogy. With this end in view it is limited to those species described in full in the body of this work, and the method of arrangement has been made to conform as nearly as possible to the chemical systom of classification there followed. Table II., on the contrary, is made to embrace all species whose crystalline system is known :

General Scheme of Classification.

## I. MALLEABLE, OR EMINENTLY SECTILE.

Many of the native metals are here included.

1. Lustre metallic.

2 Lustre unmetallic.

## II. VAPORIZABLE, OR B.B. EASILY YIELDING FUMES.

The sulphides, selenides, etc., also the sulpharsenites, sulphantimonites, etc., are here in cluded; also some native metals.

## Part I. Wholly Vaporizable.

1. Lustre unmetallic.
2. Lustre metallic.

3. Lustre unmetallic.
4. Lustre metallic.

## III. NOT MALLEABLE; NOT VAPORIZABLE, NOR EASILY YIELDING FUMES.

Part I. Lustre Metallic.

1. Streak unmetallic.-A. Infusible or nearly so ; B. Fusible.
2. Streak metallic.

## Part II. Lustre Unmetalibic.

a. Infusible.

1. Oarbonates.
b. Fusible.

## 2. Sulphates.

1 Soluble in water, or having taste.
2 Insoluble in water.
3. Chromates.
4. Silicates, Phosphates, Oxides (pt.), etc., etc.
I. Streak Colorad.

1. Infusibie, or nearly so.
2. Fusible.-A. Gelatinize with acids; B. Do not gelatinize.

## II. Streak Uncolored.

1. Infusible.-A: Gelatinize with acids; B. Do not gelatiuize.
2. Fusible-A. Gelatinize with acids.
a Hydrous; $\beta$ Anhydrous.
B. Do not gelatinize.
$\alpha$ Hydrous; $\beta$ Anhydrous.

## I. MALLEABLE OR EMINENTLY SECTILE.

## 1. Lustre metallic.

(a) Yielding B.B. no fumes.-Gold; Silver; Platinum; Palladium; Copper; Iron (pp. 221-226).
( $\beta$ ) Yielding with soda cn charcoal a silver globule.-Argentite (p. 235), and Acanthite (p. 239); yield also sulphurous fumes.-Hessite (p. 239), also telluric fumes.
2. Lustre unmetallic.

On charcoal a silver globule.-Cerargyrite (p. 260).
II. VAPORIZABLE; B.B. yielding fumes in the open tube; some require to be strongly heated.

Part I. Wholly Vaporizable; readily passing away in fumes when heated on charcoal (if pure and free from gangue).

## 1. Lustre Unmetallic.

1. Fumes sulphurous; burning with a flame.-Sulphur (p. 228).
2. Fumes antimonial.-Valentinite, senarmontite (p. 284).
3. Fumes arsenical.-Realgar (p. 231), color red; Orpiment (p. 231), color yellow.
4. Fumes mercurial.-Cinnabar (p. 240).

## 2. Lustre Metallic.

1. Fumes sulphurous; with also fumes of antimony, bismuth, etc.-Stibnite (p. 232); Bismuthinite (p. 2:32); some tetradymite (p. 233).
2. Fumes selenial or telluric.-Clausthalite (p. 236); Tetradymite (p. 233).
3. Native Arsenic, Antimony, Bismute, and Tellurium (pp. 226, 227.) Some Cinnabar (see above) has a metallic lustre.

Part II. Yielding Fumes Readily in the open Tube, but not Wholly Vaporizable.

## 1. Lustre Unmetallic.

1. Fumes sulphurous alone.-Sphalerite (p. 237), infusible; Greenockite (p. 242).
2. Fumes sulphurous, and (a) antimonial; or ( $\beta$ ) arsenical, yield a bead of silver with soda on charcoal.-(a) Miargyrite (p.249); Pyrargyrite (p. 252).-( $\beta$ ) Proustite (p. 253).

## 2. Lustre Metallic.

## 1. Fumes arsenical.

a. On charcoal a magnetic bead or mass. (a) In the closed tube unaltered.-Cobaltite (p. 246). ( $\beta$ ) Do., a sublimate of arsenic sulphide.-Arsenopyrite (p. 247), color silver-white, yields also metallic arsenic; Gersdorffite (p. 246), color silver-white to steel-gray, B.B. decrepitates; Tennantite (p. 256), color iron-black. ( $\gamma$ ) Do., a faint white crystalline sublimate of arsenous oxide.-Niccolite (p. 242), color pale copper-red.
b. With soda on charcoal a malleable bead of metallic lead.-Sartorite (p. 250), decrepitates strongly, $\mathrm{G}=5 \cdot 39$; Dufrenoysite (p. 251), $\mathrm{G}=5 \cdot 56$.
c. Do., metallic copper.-Domeykite (p. 234), color tin-white to steel-gray; EnarGIte (p. $25 \%$ ), color iron-black.
2. Fumes antimonial.
a. With soda on charcoal yield metallic copper. (The bead obtained may also be tested with borax.) (a) Contains copper and lead.-Bournonite (p. 253), color steel-gray, G. $=5 \cdot 7-5.9$. ( $\beta$ ) Contains copper and silver.-Polybasite (p. 25\%), color iron-black. ( $\gamma$ ) Teirbahedrite (p. 255).
b. Yield silver or lead but no copper. (a) Contain silver.-Dyscrasite (p. 234), G. $=9 \cdot 4-9.8$, color and streak silver-white; Freieslebenite (p. 252), G. $=6-6 \cdot 4$, color and streak light steel-gray, yields also sulphurous fumes;-Stephanite (p. 256), G. $=6 \cdot 27$, color and streak iron-black; Pyrargyrite (p. 252), and Miargyrite (p. 249), have both a red streak. ( $\beta$ ) Contain lead;-Zinkentte (p. 250), G. $=5 \cdot 30-5 \cdot 35$; Jamesonite (p. 251), $\mathrm{G} .=5 \cdot 5-5 \cdot 8$; Boulangerite (p. 254), G. $=5 \cdot 75-6$.
3. Fumes sulphurous.
a. Reaction for copper with borax.-Chalcopyrite (p. 244), color brass-yellow; Bornite (p. 237), color copper-red to pinchbeck-brown on the fresh fracture; Chalcocite (p. 239), color blackish lead-gray; Stromeyerite (p. 240), color dark steel-gray, contains also silver.
b. Yield a magnetic bead or mass on charcoal. (a) Yield free sulphur in the closed tube.—Pyrite (p. 243), G. $=4 \cdot 8-5 \cdot 2$; Marcasite (p. 247), G. $=4 \cdot 7-4 \cdot 8$; some linnæite (see below). ( $\beta$ ) Unchanged in the closed tube.-Pyrrbotite (p. 241), color reddish bronzeyellow, magnetic; Millerite (p. 241), color brass-yellow, with borax a nickel reaction; LinNAITE ( p .245 ), color pale steel-gray, contains cobalt.
c. Yields metallic lead on charcoal.-Galentte (p. 235), color lead-gray.
$d$. Not included in the above.-Molybdentte (p. 233).
4. Fumes mercurial.-Amalgam (p. 225).
5. Fumes telluric. (a) Contain silver or gold.-Sxlvantte (p. 248), color steel-gray to silver-white, brittle; Hessite, Petzite (p. 238), color lead to steel-gray, sectile. ( $\beta$ ) Contains lead.-Nagyagite (p. 249), color black lead-gray, foliated.

## III. NOT MALLEABLE; NOT VAPORIZABLE, NOR EASILY YIELDING FUMES.

Part I. Lustre Metallic, or Submetallic.

## 1. Streak Unmetallic.

## A. Infusible, or Fiusible with great difficulty.

a. Reaction for manganese with borax.
(a) Anhydrous.-PYROLUsTre (p. 278), G. $=4 \cdot 82 . \mathrm{H} .=2-2 \cdot 5$, streak black (braunite, hausmannite, (p. 277); Franklinite (p. 273), often in octahedrons, G. $=5.07$, $\mathrm{H} .=5.5-6.5$; streak dark reddish brown; yields zine B.B. Some Columbite (pp. 360, 423).
( $\beta$ ) Hydrous. - Manganite (p. 280); Pstlomelane (p. 282); Wad (p. 283).
b. Reaction for iron : become magnetic upon ignition in R.F.
(a) Anhydrous.-MAGNETite (p. 272), streak black, magnetic ; Hematite (p. 268), streak cherry-red. Contain titanium.-Menaccanite (p. 269), G. $=45-5$, streak black to brownish-red; Rutile (see $d$ below). Contain tantalum or columbium.--Tantalite (p. 359 ), G. $=7-8$; Columbite ( p .360 ), G.5•4-6.5. Contains chromium. Chromite (p. 274), streak brown.
${ }^{(\beta)}$ Hydrous.-Limontte (p. 280), streak yellowish-brown, G. $=3 \cdot 6-4$, only massive; Göthite (p. 280), streak same, G. $=4-4 \cdot 4$, often in crystals; Turgite (p. 279), streak red, decrepitates strongly B.B.
c. Reaction for zinc on charcoal.-Zincite (p. 266), streak orange-yellow.
d. Reaction for titanium.-Rutile (p 276); Octabedrite (p. 277 ); Brookite (p. 277); Perofskite (p. 270).-Euxenite (p. 362), contains columbium.
e. No reactions as above.-Yttrotantalite (p. 361).

## B. Fusible.

a. Reaction for iron, become magnetic.-Ilvaite (p. 309), G. $=3 \cdot 7-4 \cdot 2$; Allantte (p. 308), $\mathrm{G} .=3-4 \cdot 2 ;$ Wolframite (p. 383), G. $=7 \cdot 1-7 \cdot 5$; Samarskite (p. 361), G. $=5 \cdot 45-5 \cdot 69$.
b. Reaction for copper.-Tenorite (p. 267); Cuprite (p. 266).

## 2. Streak Metallic.

No metallic bead.-Graphite (p. 230); Iridosmine (p. 224).

## Part II. Lustre Unmetallic.

1. CARBONATES: when pulverized cffervesce (give off $\mathrm{CO}_{2}$ ) with hydrochloric or nitric acid, sometimes only on the addition of heat (p. 202).*

## 1. Infusible.

a. No metallic reaction, or only traces; assay alkaline (p. 205) after ignition.
(a) Anhydrous.-Effervesce freely in the mass in cold dilute acid; Calcite (p. 398), G. $=2 \cdot 5-2 \cdot 8$; Aragonite (p.405), G. $=2 \cdot 9$; Barytocalcite (p. 408), contains barium. Effervescence wanting or feeble, unless very finely pulverized or heated; Dolomite (p. 401); Magnesite (p. 402).
( $\beta$ ) Hydrous.-Hydromagnesite (p. 409).
b. A decided reaction for iron; become magnetic upon ignition.

Siderite (p. 403); Ankerite (p. 402). Also mesitite, pistomesite (p. 403), and some varieties of the preceding carbonates.
c. A decided reaction for manganese with borax.

Rhodochrosite (p. 403). Also some varieties of the preceding carbonates.
d. Reaction for zinc on charcoal.
(a) Anhydrous.-Smithsonite (p. 44). (8) Hydrous.-Hydrozincite (p. 410).

## 2. Fusible.

a. No metallic reaction, or only traces; assay alkaline after fusion.
(a) Anhydrous.-Witherite (p. 406), (ì. $=4 \cdot 3$, B.B., a green flame (baryta); Strontianite ( p .406 ), $\mathrm{G} .=3 \cdot 6-7$, B.B., a strontia-red flame.
( ${ }^{\beta}$ ) Hydrous.-Gay-Lussite (p. 409); Trona (p. 408).
$b$. Reaction for lead on charcoal.
Cerussite (p. 407); Phosgenite (p. 408), contains lead chloride; Leadhillite (p. 390) contains lead sulphate.
c. Reaction for copper with borax.

Hydrous-MAlachite (p. 411), color green; Azurite (p. 411), color azure-blue.
d. Reaction for bismuth on charcoal.

Hydrous.-Bismutite (p. 412).

[^68]2. SULPHATES: Yield a sulphide with soda on charcoal (p. 209),* which when moistened blackens a surface of polished silver.

## 1. Soluble in Water: having taste.

a. Glaubertte (p. 391); Mirabiltte (p. 392) ; Polyhalite (p. 393); Epsomite (p. 394); Alums (p. 395).
b. Copperas group : Vitriols.-Chalcanthite, etc. (p. 394.)

## 2. Insoluble in Water: having no taste.

a. Yield no metallic bead. Fusible; assay alkaline after fusion.
(a) Anhydrous.-Barite (p. 387), G. $=4 \cdot 3-4 \cdot \%$, a yellowish-green flame B. B.; Celesтtтe (p. 388), $\mathrm{G} .=3 \cdot 92-397$, a strontia-red flame B.B.; Anhydrite (p. 889), G. $=2 \cdot 9-2 \cdot 99$. a reddish-yellow flame.
( $\beta$ ) Hydrous: Gypsum (p. 392), H. $=1 \cdot 5-2, \mathrm{G} .=2 \cdot 3$.
b. Reaction for aluminum ; a bluc color with cobalt solution after ignition.

Hydrous: Aluminite (p. 395).
c. Reaction for lead on charcoal.

Fusible.-Anglesite (p. 389); Leadhillite (p. 390), contains lead carbonate.
d. Reaction for copper with borax.

Brociiantite (p. 396); Linarite (p. 396).
$e$. Reaction for iron : becomes magnetic after ignition on charcoal.
Copiapite (p. З39).
3. CHROMATES: Afford a chromium reaction with borax (p. 208). All brightiy colored, and having a colored streak.

Crocoite (p. 385), color hyacinth-red, streak orange-yellow; Phgnicocerorte (p. 386), color cochineal- to hyacinth-red, streak brick-red; VAUQUELinite (p. 386), color green to brown, streak greenish or brownish.
4. SILICATES, PHOSPHATES, OXIDES (in part), etc
I. Streak Colored: having a decided color.

## 1. Infusible, or Fusible with great Difficulty.

a. Reaction for iron, magnetic after ignition in R.F.
(a) Anhydrous.-Hematite (268), streak cherry-red ; some Rutile (see e below).
(в) Hydrous.-Limonite (p 280), streak yellowish-brown; Göthite (p. 280), streak same ; Turgite (p. 2i9),streak red, decrepitates B.B.
b. Reaction for manganese with borax.

Hydrous.-Wad (p. 283); Psilomelane (p. 282).
c. Reaction for zinc on charcoal.

Zincite (p. 266); streak orange-yellow.
d. Reaction for copper: yield metallic copper with soda on charcoal.

Hydrous.-Droptase (p. 301), color emerald-green.
$e$. Reaction for titanium : with metallic tin on evaporation a violet color to the hydrochloric acid solution, sometimes after fusion with potassium bisulphate.

Rutile (p.) 276), G. $=4 \cdot 2$; WARWICKITE (p. 382 ), $\mathrm{G} .=3 \cdot 3$, moistened with sulphirio acid gives a green flame B. B. (boron).-Soine Pyrochlore (p. 359); and Perofskite (p. 270). $f$. Reaction for tin: yields the metal with soda on charcoal.

Cassiterite (p. 275), G. $=6 \cdot 4-7 \cdot 1$.
g. Not included in the above.
(a) Phosphates: moistened with sulphuric acid give a bluish-green flame B.B.Monazite (p.368). G. $=4 \cdot 9-5 \cdot 26 ;$ Xenotime (p. 364), $G,=4 \cdot 4 \cdot 5-4 \cdot 56$.
${ }^{(\beta)}$ Pyrochlore (p. 359), G. $=4 \cdot 2-4 \cdot 35$; Fergusonite (p. 362).

[^69]
## 2. Fusible without very great Difficulty.

## A. Gelatinize with Acid ( $p$. 203).

Give a reaction for iron.
Ilvaite (p. 309), yields little or no water, H. $=5 \cdot 5-6, G .=3 \cdot 7-4 \cdot 2$, streak black, Hisingerite (p. 354), yields much water, H. $=3$, G. $=3.045$, streak yellowish-brown; Allanite (p. 308), H. $=5 \cdot 5-6, \mathrm{G} .=3-4 \cdot 2$, streak gray.

## B. Do not Gelatinize with Acid.

1. Arsenates: give arsenical fumes on charcoal ; after thorough roasting yield metallic reactions as follows:
a. Reaction for iron: becomes magnetic after ignition.

Pharmacosiderite (p. 376), color olive-green to yellowish-brown stc.
b. Reaction for cobalt with borax.

Erythrite (p. 372), color rose-red.
$c$. Reaction for copper with borax; also give a green flame B.B.
Hydrous.-Olivenite (p. 373), G. $=4 \cdot 1-4 \cdot 4$, color olive-green to brown; Liroconite ( p . 374), G. $=2 \cdot 88-2 \cdot 98$, color sky-blue to verdigris-green; Clinoclasite (p. 374), G. $=3 \cdot 6-3 \cdot 8$, color dark-green (some libethenite, see below).
2. No arsenical fumes; reaction for iron: become magnetic after fusion.
a. Anhydrous.-Reaction for titanium: Schorlomite (p. 337), H. $=7-7 \cdot 5, \mathrm{G} .=3 \cdot 862$. massive.-Reaction for manganese: Triplite (p. 569), H. $=3 \cdot 44-3 \cdot 88$, G. $=4-5 \cdot 5$, colors the flame bluish-green.-Struture micacecous : Lepidomelane (p. 313),
b. Hydrous.-Give a bluish-green flame B. B.: Vivianite (p. 371), H. $=1 \cdot 5-2, G .=$ 2.58-2.68, streak colorless to indigo-blue (on exposure); Dufrentre (p. 378), H. $=3 \cdot 5-4$, G. $=3 \cdot 2-3 \cdot 4$, streak siskin-green.
3. No arsenical fumes; reaction for copper with borax, vield an emerald-green flame B.B.
(a) Anhydrous.-Cuprite (p. 266) ; Tenorite (p. 267), color steel-gray to black.
( $\beta$ ) Hydrous. - Structure micaceous; Torbernite (p. 378), H. $=2-2 \cdot 5, \mathrm{G} .=3 \cdot 4-3 \cdot 6$, -Libethente (p. 373), H. = 4 , G. $=3 \cdot 6-3.8$; Pseudomalachite (p. 374), H. $=4 \cdot 5-5$, G. $=$ 4-4.4; Аtacamite (p. 261), H. $=3-3 \cdot 5$, G. $=3 \cdot 8$

## II. Streak Uncolored ; sometimes slightly grayish, yellowish, etc.

## 1. Infusible, or Fusible with much Difficulty.

## A. Gelatinize with Acid forming a stiff Jelly.

a. Reaction for iron with the fluxes.

Chrysolite (p. 300); Chondrodite, Humite (p. 326-329), yield fluorine.
b. Reaction for zinc on charcoal, after being heated with soda.
(a) Anhydrous.-Willemite (p. 301).
( $\beta$ ) Hydrous.-Calamine (p. 329).
c. Reaction for aluminum ; a blue color with cobalt solution after ignition.

Allophane (p. 341), amorphous.
d. Reaction for magnesium: pink color with cobalt solution after ignition.

Sepiolite (p. 349), in soft, white, compact masses.

## B. Do not form a perfect Jelly with Acid.

## 1. Hydrous.

a. Reaction for aluminum : a blue color with cobalt solution after ignition.

1. Phosphates: give a bluish-green flame B.B., especially after being moistened with sulphuric acid.-Wavellite (p. 376), color white to green to black; Lazulite (p. 375),
color azure-blue, with borax an iron reaction; Turquois (p. 377), color sky-blue to applegreen, with borax a copper reaction.

2 Hydrous silicates.-Structure micaceous; Margarite (p. 35i), yields much water; also some hydrous micas (see p. 353).

Kaolinite (p. 351 ) usually compact, soft, unctuous; Pyrophyllite (p. 349), soft, yields much water.
3. Oxides.-Gibssite (p. 282), $\mathrm{H} .=2 \cdot 5-3 \cdot 5$, usually in stalactitic forms; Diaspore (p. 279), $\mathrm{H}_{ \pm}=6 \cdot 5-7$, in crystals, scales, and foliated, usually decrepitates B.B.
$b$. Reaction for magnesium: a pink color with cobalt solution after ignition.
Brucite (p. 281), soluble in acids; TalC (p.348), yields water only on intense ignition. Also some serpentine (see below).
c. No reactions as above.

Opal (p. 283), H.=6-7.-Serpentine (p. 350), H. $=2 \cdot 5-4$; Chloritoid (p. 358), H. $=5 \cdot 5-6$; Genthite (p. 351), yields a reaction for nickel with borax.-Chrysocolla (p. $338), \mathrm{H} . \doteq 2-4$, colors the flame emerald-green (copper).

## 2. Anhydrous.

a. Reaction for aluminum : (When of great hardness, pulverizing is necessary).
(a) Decomposed by acids.-Leucite (p. 318), $\mathrm{H} .=5.5-6$.
${ }^{(\beta)}$ Structure eminently micaceous.-Muscovite (p. 313).
( $\gamma$ ) Corundum ( p .267 ), $\mathrm{H} .=9, \mathrm{G} .=4$, rhombohedral.
Chrysoberyl (p.274), $\mathrm{H} .=8.5, \mathrm{G} .=3 \cdot 7$, color green.
Topaz (p 332), H. $=8, \mathrm{G} .=35$, in prisms of $124^{\circ}$, cleavage basal perfect.
Rubellite (p. 330), $H .=7.5, G .=3$, in three- or six-sided prisms, color violet, rosered, reaction for boron ( p .211 ).
$\left\{\begin{array}{l}\text { Andalusite (p. 331) } \\ \text { F }\end{array}=7 \cdot 5, \mathrm{G} .=3 \cdot 2\right.$, in prisms of $93^{\circ}$.
$\{$ Fibrolite (p. 331), H. $=6-7$, G. $=3 \cdot 2$, brilliant diagonal cleavage
(Cyanite (p. 332), H. $=5-7, G .=3 \cdot 6$, usually in bladed crystals, color blue to gray.
b. Reaction for magnesium : a pink color with cobalt solution after ignition.

Talc (p. 348), soft, foliated, yields water upon intense ignition.
Enstatite pt. (p. 290), Н. $=5.5$, cleavage prismatic $93^{\circ}$.
Spinel pt. (p. 271), H. $=8$, commonly in octahedrons.
c. Reaction for tin: metallic globules with soda on charcoal.

Cassiterite (p. 275), G. $=6 \cdot 4-7 \cdot 1$. Also some Pyrochlore (p. 359).
d. No reactions as above.

1. Hardness 7, or above 7.

Spinel (p. 271), H. $=8, G=3 \cdot 5-4 \cdot 1$, occurs in octahedrons.
Gahnite (p. 272), $\mathrm{H} .=7 \cdot 5-8, G .=4 \cdot 4-4 \cdot 9$, octahedral, when mixed with borax gives a zinc coating, on charcoal.

BERYL (p. 299), $\mathrm{H}_{\mathrm{C}}=7 \cdot 5-8, \mathrm{G} .=2 \cdot 6-2 \cdot 7$, always in hexagonal prisms.
Phenacite (p. 301), H. $=7 \cdot 5-8, G .=3$, rhombohedral.
Ouvarovite (p. 304), $\mathrm{H} .=7 \cdot 5$, G. $=3 \cdot 5$, color green, chromium reaction.
Zircon (p. 304), H. $=7 \cdot 5$, G. $=4 \cdot 05-4 \cdot 75$, zirconia reaction (p. 213) often in square prisms.

Staurohite (p. 336), H. $=7, \mathrm{G} .=3 \cdot 4-3 \cdot 8$, always crystallized, $I \wedge I=123^{\circ}$.
Iolite (p. 311) $\mathrm{H}_{.}=7 \cdot 7 \cdot 5, \mathrm{G} .=2 \cdot 6$, color blue, lustre glassy.
Quartz (p. 284), $\mathrm{H} .=7, \mathrm{G} .=2 \cdot 6$, and Tridymite (p. 288), G. $=2 \cdot 3$.
2. Hardness below 7.
(a) Give a bluish-green flame when moistened with sulphuric acid; Xenotime (p. 364) ; Monazite (p. 368); Apatite (p. 364).
${ }^{(\beta)}$ Reaction for titanium.-RUTILE (p. 276); Brookite (p. 27\%); Octahedrite (p. 277), always in square octahedrons; Perofskite (p. 270).
(ү) Reaction for tungsten.-Scheelite (p. 384), H. $=6$, G. $=4 \cdot 5-5$.
(8) Not included in the above; Enstattee (p. 290) - Diallage (p. 293); AnthophylLITE (p. 295).

## 2. Fustble.

## A. Gelatinizing with Acid: forming a stiff Jelly upon Evaporation.

## 1. Hydrous.

a. Hardness 5, or above 5.

Datolite (p. 334 ), in glassy crystals, also rarely massive, never fibrous, fuses with a green flame (boron).

Natrolite (p.342), G. $=2 \cdot 17-2 \cdot 25$, fuses quietly and easily to a colorless glass.
Scolecite (p. 343), Thomsonite (p. 342), on fusion often curl up in worm-like forms.
b. Hardness below 5 .

Gmelinite (p. 345), $\mathrm{H}=4^{\circ} 5$, in hexagonal or rhombohedral crystals.
Phillipsite ( p .345 ), $\mathrm{H}_{\mathrm{i}}=4-4 \cdot 5$, in twinned crystals.
Laumontite ( p .338 ), $\mathrm{H} .=3 \cdot 5$, becomes opaque on exposure.
Pectolite and Analcite are decomposed by acid with the separation of gelatinous silica, but do not form a stiff jelly.

## 2. Anhydrous.

a. With hydrochloric acid give off sulphuretted hydrogen.

DANALITE (p. 302), with soda on charcoal gives a zine coating, color flesh-red to gray. Helvite (p. 302), manganese reaction with borax, color yellow.
b. With soda on charcoal a sulphur reaction.

Hauynite (p. 318), color sky-blue.
c. Sodalite (p. 317), reaction for chlorine.

Wollastontte (p. 291), color white, lustre vitreous.
Nephelite (p. 316), hexagonal.

## B. Do not form a perfect Jelly with Hydrochloric Acid.

## 1. Hydrous.

1. Structure eminently micaceous.

Chlorites: Penninite (p. 355); Ripidolite (p. 356); Prochlorite (p. 357); laminæ tough but not elastic, colors green to black; only partially attacked by acid.

Vermiculites: Jefferisite (p. 355); also pyrosclerite, etc., colors mostly brown, yellow, also green, B.B. exfoliate largely, decomposed by acid with the separation of silica.

Lepidomelane (p. 313), color black, yields a magnetic globule.
Autunite p. (379), $\mathrm{H}=2-2 \cdot 5$, color bright yellow.
Fahlunite (p. 353), has a more or less distinct micaceous structure.
2. Structure not micaceous.

1. Reaction for iron: leave a magnetic residue on charcoal.
(a) Arsenates: give arsenical fumes on charcoal.-Scorodite (p. 375), orthorhombic;

Pharmacosiderite (p. 376), isometric.
${ }^{(\beta)}$ Phosphates: give a bluish-green flame after moistening with sulphuric acid.
Childrenite (p. 377), reacts for manganese, fuses only on the edges, $\mathrm{H} .=4 \cdot 5-5$.
Viviante (p. 371), $\mathrm{H} .=1 \cdot 5-2$, fuses easily to a magnetic globule.
2 Reaction for arsenic on charcoal.
Pharmacolite (p. 370).
8. Borates: give a deep-green flame after moistening with sulphuric acid.

Borax (p. 381); Boracite (p. 381); Ulexire (p. 381); Sussextte (p. 380).
4. Not included above.
(a) Hardness 5, or above 5 (apatite $=5$ ).

Prehnite ( p .340 ), $\mathrm{H}_{0}=6-6^{\circ} 5$, color apple-green to white.
Analctte (p. 343), $\mathrm{H}_{.}=5-5.5$, fuses quickly to a clear glass.
Pectolite ( p .337 ), $\mathrm{H} .=5$, usually in aggregations of acicular crystals.
Apopiyllite (p. 340), H. $=4 \cdot 5-5$, B.B. a violet-blue flame.
( $\beta$ ) Hardness below 5.
Pinite (p. 352), H. $=2 \cdot 5-3 \cdot 5$, compact.
Pachnolite (p. 265), H. $=2-4$, yields fluorine.
Chabazite (p. 344), $\mathrm{H} .=4-5$, rhombohedral.
Apophyllite (p.340), $\mathrm{H} .=4 \cdot 5-5$, tetragonal.
Harmotome (p. 346), $\mathrm{H} .=4 \cdot 5$, usually in compound crystals.
Stilbite (p. 346), H. $=3 \cdot 5-4$.
Heulandite (p. 347), H. $=3 \cdot 5-4$.

## 2. Anhydrous

1. Yield metallic lead, with soda on charcoal.

Pyromorphite (p. 366), color green, gives a bluish-green flame on fusion.
Mimetite (p. 366), color yellow to brown, yields arsenical fumes on charcoal.
Vanadinite ( $\mathrm{p} .36^{\circ}$ ), color brownish-yellow to reddish-brown, with borax R.F. an emerald-green bead.

Wulfenite (p. 384), color bright yellow to red, reaction for tungsten.
2. Reaction for fluorine, with sulphuric acid.
(a) Give a bluish-green flame after moistening with sulphuric acid.

Amblygonte (p. 369), gives a lithia-red to the flame.
Triplite (p. 369), a strong manganese reaction.
Wagnerite (p. 368), color yellow to grayish.
${ }^{\beta}$ ) Fluorite (p. 263), cleavage octahedral, perfect.
Cryolite (p. 264), fusible in the flame of a candle.
Lepidolite (p. 314), color pink, structure micaceous.
3. Reaction for lithia: give a purple-red color to the flame.

Spodumexe (p. 295), H. $=6 \cdot 5-7, \mathrm{G} .=3 \cdot 13-3 \cdot 19$.
Triphylite (p. 369), H. $=5$, $\mathrm{G} .=3 \cdot 54-3 \cdot 6$, gives a bluish-green color to the extremity of the flame.

The mica lepidolite, and also some biotite, give a lithia flame.
4. Reaction for iron with the fluxes.

Vesuvianite (p. 305), tetragonal, $\mathrm{H} .=6.5$.
Epidote (p. 307), monoclinic, H. $=6-7$.
Garnet pt. (p. 302), is isometric, $\mathrm{H}_{\mathbf{1}}=6 \cdot 5-7 \cdot 5$.
Lepidomelane (p. 313), structure micaceous.
Hypersthene (p. 290), orthorhombic.
Here fall also dark-colored varieties of Amphibole (p. 296), and Pyroxene (p. 292).
5. Reaction for manganese with borax.

Rhodonite (p. 294), color usually rose-red.
Spessartite (manganese garnet, p. 304).
6. Reaction for titanium.

Titanite (p. 335).
7. Reaction for tungsten.

Scheelite (p. 384).
8. Not included in the above.
$H_{\text {alite }}$ (p. 259), Sylvite (p. 260), soluble in water.
Micas (pp. 311-314), structure eminently micaceous.
Apatite (p. 364), H. $=5, \mathrm{G} .=2 \cdot 9-3 \cdot 25$, a bluish-green flame after moistening with sulphuric acid.

Pyroxene (p. 292), H. $=5-6, G .=3 \cdot 2-3 \cdot 5$, monoclinic, angle of prism $93^{\circ}$.
Amphibole ( p .296 ) , $\mathrm{H} .=5-6, \mathrm{G} .=2 \cdot 9-3 \cdot 4$, monoclinic, angle of prism (cleavage perfect) $124 \frac{1}{2}^{\circ}$

Scapolites (pp. 315-316), H. $=5-6 \cdot 5, \mathrm{G} .=2 \cdot 5-2 \cdot 8$, tetragonal; B.B. fuse with intu-- mescence to a blebby glass.

Zoisite (p. 308), H.=6-6.5,G. $=3 \cdot 1-3 \cdot 38$, orthorhombic; B. B. swells up and fuses to a blebby glass.

F'eldspars (pp. 319 to 326 ), $\mathrm{H} .=6-7$, G. $=2 \cdot 6-2 \cdot 8$, cleavage in two directions at right angles or nearly so; B.B. fuse quietly to a clear glass.

Axintes (p. 310), H. $=6 \cdot 5-7, \mathrm{G}_{\mathrm{F}}=3 \cdot 27 ; \mathrm{B} . \mathrm{B}$. reaction for boron.
Tourmaline (p. 329), H. $=7$, G. $=2 \cdot 9-3 \cdot 3$; no distinct cleavage, commonly in three or six-sided prisms; B.B. reaction for boron.

Garnet (p. 302), $\mathrm{H} .=6 \cdot 5-7 \cdot 5, G .=3 \cdot 15-4 \cdot 3$, isometric.

## TABLE II.

## Minerals Arranged According to their Crystallization.

The following table contains the names of all distinct species whose Crystalline System is known. For conventence, however, the names of those which are described in detail in the body of the work are printed in small capitals. The species in each group are arranged according to their specific gravities.

## I. CRYSTALLIZATION ISOMETRIC.

A. Lustre Unmetallic.

|  | Spec. Gravity | Hardness. |  | Spec. Gravity | Hardness |
| :---: | :---: | :---: | :---: | :---: | :---: |
| Sal Ammoniac (p. 260 ). | 1.53 | 1.5-2 | Arsenolite (p. 284) | $3 \cdot 70$ | 1.5 |
| Alum (p. 39J)........ | 1.5ั6-2 | 2-2.5 | Nantokite (p. ©60). | 3.93 | 2-2.5 |
| Faujasite (p. 344) | $1 \cdot 92$ |  | Spinel (p. 271). | 3•5-4•1 |  |
| Sylvite (p. 260). | 1-9-2 | 2 | Hercynite (p. 272). | 3.9-3.95 | 7•5-8 |
| Halite (p. 259). | $2 \cdot 1-2 \cdot 26$ | $2 \cdot 5$ | Alabandite (p. $2: 3$ ) | 3•95-4 | 3.5-4 |
| Chlorocalcite (p. 260 |  |  | Percylite (p. 262). |  | $2 \cdot 5$ |
| Kremersite (p. 261) |  |  | Sphalerite (p. 2: 7) | 3.9-4'2 | 3•5-4 |
| Sodalite (p. 317). | 2.14-2.4 | 5•5-6 | $?$ Perofskite (p. 2ij0). | $4 \cdot 04$ |  |
| analcite (p. 343) | 2.2-2:29 | 5-5.5 | Chrompicotite (p. 274) . | $4 \cdot 12$ | 8 |
| Nosite (p. 318) | 2.25-2.4 | $5 \cdot 5$ | Tritomite (p. 340) | 3.9-4 7 | $5 \cdot 5$ |
| Ralstonite ip. 265 | $2 \cdot 4$ | $4 \cdot 5$ | Pyrochlore (p. 859 ). | 4:2-4.35 | 5-5.5 |
| Hauynite (p. 318). | 2-4-2.5 | 5-5.5 | Pyrrhite (p. 359) . |  |  |
| $?$ Leveite (p. 318) | 2.4-2.56 | 5•5-6 | Gabnite (p. 2i2). | 4-4.6 | 7-5-8 |
| Oldhamite (p. 235) | $2 \cdot 58$ | 4 | Thorite (p. 340) | 4.3-5.4 | $4 \cdot 5$ |
| Pollucite (p. 299).. | $2 \cdot 9$ | 6.5 | Hatchettolite (p. 428). . | 4.77-4.9 |  |
| Pharmacosiderite (p. |  |  | Manganosite (p. 431)... | $5 \cdot 118$ | $5 \cdot 6$ |
| 376) | 2.9-3 | $2 \cdot 5$ | Senarmonite (p. 284). . | 5-2-5•3 | 2-2.5 |
| Boracite (p. 381) | $2 \cdot 97$ | 7 | Embolite (p. 260). | 5-3-5-4 | 1-1.5 |
| Fluorite (p. 263) | $3 \cdot 19$ | 4 | Microlite (p. 359). | 5•25-5.66 |  |
| Nitrobarite (p. 433). | $3 \cdot 16-3 \cdot 4$ |  | Cerargyrite (p. 260).. | 5 | 1-1.5 |
| Helvite (p. 302). | 3-1-3.3 | 6-6.5 | Huantajayite (p.259). . |  |  |
| Garnet (p. 302). | 3•15-4*3 | 6.5-7.5 | Iodobromite (p. 429). . | $5 \cdot 71$ |  |
| Danalite (p. 302) | $3 \cdot 43$ | 5.5-6 | Bromyrite (p. 260). | 5.8-6 | 2-3 |
| Hauerite (p. 244). | $3 \cdot 46$ | 4 | Cuprite (p. 266) | 5•8-6.15 | 3.5-4 |
| Diamond (p. 228) | 3.53 | 10 | Eulytite (p. 302). | 5-9-6 | $4 \cdot 5$ |
| Periclasite (p. 267). | $3 \cdot 67$ | 6 | Bunsenite (p. 267) | $6 \cdot 4$ | $5 \cdot 5$ |

B. Lustre Metallic (and Submetallic).

|  | Spec. Gravity | Hardness. |  | Spec.Gravity | Hardness |
| :---: | :---: | :---: | :---: | :---: | :---: |
| Cubanite (p. 245) | 4.03-4*2 | 4 | Skutterudite (p. 246) | 6.7-6.8 |  |
| Prrofskite (p. 270) | 404 | $5 \cdot 5$ | Polyargyrite (p. 257) | 6.97 |  |
| Chromite (p. 274). | 4 3-4.6 | $5 \cdot 5$ | Laurite (p. 247)..... | $6 \cdot 99$ | 7 above |
| Tennantite (p. 256 ) | 4-4-4.5 | 3.5-4 | Argentite (p. 235) | 7-2-7-4 | 2-2. |
| Binnite (p. 251).. | $4 \cdot 48$ | $4 \cdot 5$ | Beegerite (p. 421). | $7 \cdot 27$ |  |
| Magnesioferrite (p. 273). | 4.6 | 6-6.5 | Galenite ip. 235) | 7.25-7.7 | $2 \cdot 5$ |
| Jacobsite (p. 272) | 4.75 | 6 | Iron (p. 226). | $7 \cdot 3-7 \cdot 8$ |  |
| Corynite (p. 247) | 4.99 | $4 \cdot 5-5$ | Cleveite (p. 423) |  | $5 \cdot 5$ |
| Bornite (p. 237) | 4-4-5.5 | 3 | Metacinnabarite (p. 241) | 7.5-7•7 |  |
| Tetrahedrite (p. 255) | $4 \cdot 5-5 \cdot 1$ | 3-4.5 | Clausthalite (p. 236). | 7.6-8.8 | 2.5 |
| Linneite (p. 245)... | 4.8-5 | $5 \cdot 5$ | Naumannite (p. 235). | 8.0 |  |
| Prrite (p. 243). | $4 \cdot 8-5 \cdot 2$ | 6-6.5 | Altaite (p. 237). | $8 \cdot 16$ | 3-3.5 |
| Magnetite (p 272) | 4.9-5 2 | 5.5-6.5 | Copper (p. 225). | $8 \cdot 84$ | 2.5- |
| Franklintte (p. 273 ) | 5.07-5.09 | 5.5-5.5 | Uraninite (p. 274) | 8-9-25 |  |
| Julianite (p. 256 ) | $5 \cdot 12$ | soft | Silver (p. 223). | $10 \cdot 1-11 \cdot 1$ | $2 \cdot 5-3$ |
| Grünauite (p. 237) | $5 \cdot 13$ | $4 \cdot 5$ | Palladium (p. 224) | 11.3-11.8 | $4 \cdot 5-5$ |
| Gersdorffite (p. 246) | 5.6-6.9 | $5 \%$ | Amalgam (p. 225) |  | 3.3-5 |
| Cobaltite (p. 246 ) .... | 6-6.3 | $5 \cdot 5$ | Gold (p. 221).. | 15.6-19.5 | 2.5-3 |
| Ullmannite (p. 247). | $6.2-6.5$ $6.4-7.2$ | $5-5 \cdot 5$ | Platinum (p. 2 Platiniridum ( | $\begin{aligned} & 16-19 \\ & 22 \cdot 6-23 \end{aligned}$ | 4-4\% |
| Smaltite (p. 245). | 6.4-7.2 | $5 \cdot 5-6$ | Platiniridum ( p | 22.6-23 | 6-7 |

The commonly oczurring forms of some of the Isometric minerals are as follows:
1.-Octahedrons.-Alum; Chromite; Cuprite; Diamond; Franklinite; Hatchettolite; Magnetite; Microlite; Pyrochlore; Ralstonite; Spinel (incl. hercynite, etc.); Uraninite (and cleveite). Also Laurite; Pyrrhite; Senarmontite, and less commonly Galenite; Fluorite.
2. Cubes.-Boracite; Cerargyrite; Fluorite; Galenite; Halite; Percylite; Perofskite; Pharmacosiderite; Pyrite; Sylvite.
3. Dodecakedrons.-Amalgam; Cuprite ; Garnet; Magnetite.
4. Trapezohedrons.-Garnet; (?) Leucite; Analcite.
5. Pyritohedrons.-Cobaltite ; Gersdorffite ; Hauerite; Pyrite.

The Cleavage of Halite, Sylvite, Periclasite, Galenite is eminently cubic;-of Fluorite, Magnetite, Diamond, eminently octahedral;-of Sphalerite, eminently dodecahedral.

## II. CRYSTALLIZATION TETRAGONAL.

A. Lustre Unmetallic.

|  | Spec. Gravity | Hardness. |  | Spec. Gravity | Hardness. |
| :---: | :---: | :---: | :---: | :---: | :---: |
| Mellite (p. 412). | 1.55-1.65 | 2-2.5 | Adelpholite (p. 363) | $3 \cdot 8$ | $3 \cdot 5-4 \cdot 5$ |
| Apophyllite (p. 340). | 2•3-2.4 | $4 \cdot 5$-5 | Octahedrite (p. 277). . | $3 \cdot 8-3 \cdot 95$ | 5.5-6 |
| Lœweite (p. 394). | $2 \cdot 38$ | 2•5-3 | Rutile (p 276). | $4 \cdot 18-4 \cdot 25$ | 6-6.5 |
| ? Leucite (p. 318) | $2 \cdot 4-2 \cdot 56$ | 5•5-6 | Xenotime (p. 364). | $4 \cdot 45-4 \cdot 56$ | 4-5 |
| Sarcolite (p. 316)... | 2.5-2.9 | 6 | Zircon (p. 304). | 4-4•75 | $7 \cdot 5$ |
| Wernertte (p.316). | 2•63-2.8 | 5-6 | Azorite (p. 359). |  |  |
| Meionite (p. 315). | 2•6-2 74 | 5-5--6 | Romeite (p. 370 ) | $4 \cdot 7$ | 5-6 |
| Edingtonite (p. 341) | $2 \cdot 7$ | 4-4:5 | Sipylite (p. 4:6) | $4 \cdot 89$ | 6 |
| Chiolite (p. 264)... | 2.7-2.9 | 4 | Monimolite (p. 370 ). | 5.94 | $4 \cdot 5-5$ |
| Sellaite (p. 264). | $2 \cdot 97$ | 5 | Scheelite (p. 3S4).. | 5.9-6.08 | $4 \cdot 5-5$ |
| Gehlenite (p. 331). | $2 \cdot 9-3 \cdot 07$ | 5•5-6 | Phosgenite (p. 408). | 6-6.3 | 2•75-3 |
| Mellilite (p. 306). | 2.9-3•1 | 5 | Calomel (p. 260). | 6.48 | 1-2 |
| Chodneffite (p. 264) | $3 \cdot 0$ |  | Cassiterite (p. 275). | $6 \cdot 4-7 \cdot 1$ | 6-7 |
| Zeunerite (p. 379).. | $3 \cdot 2$ | 2-2 5 | Wulfenite (p. 384). . | 6-7.01 | 2•75-3 |
| Vesuvianite (p. 305).. | $335-3 \cdot 45$ | $6 \cdot 5$ | Eosite (p. 385)... |  | 3-4 |
| Torbernite (p 378)... | $3 \cdot 4-3 \cdot 6$ | 2-2.5 | Matlockite (p. 262) | $7 \cdot 2$ | 2•75-3 |
| Kochelite (p. 363 ). | 374 | 3-3.5 | Stolzite (p. 384) | $7 \cdot 9-8 \cdot 13$ | 2•\%0-3 |

B. Lustre Metallic (and Submetallic).

|  | Spec. Gravity | Hardness. |  | Spec. Gravity | Hardness. |
| :---: | :---: | :---: | :---: | :---: | :---: |
| Chalcopyrite (p. 244). | $4 \cdot 1-4 \cdot 3$ | $3 \cdot 5-4$ | Braunite (p. 277). | 4.75-4.8 | 6-6.5 |
| Stannite (p. 245)..... | 4 3 -4 5 |  | Fergusonite (p. 362). | $5 \cdot 84$ | 5.8-6 |
| Hausmannite (p.27\%). | $4 \cdot 72$ | $5-5 \cdot 5$ | Nagyagite (p. 249).. | 6•85-7.2 | 1-1.5 |

III. CRYSTALLIZATION HEXAGONAL.
A. Lustre Unmetailic.

|  | Spec. Gravity | Hardness. |  | Spec. Gravity | Hardness |
| :---: | :---: | :---: | :---: | :---: | :---: |
| Ettringite (p. 395) | 1.75 | 2 | Pyrosmalite (p. 340) | 3-3.2 | 4-4.5 |
| Coquimbite (p. 395). | 2-2.1 | 2-2.5 | Dreelite (p. 390) R . | 3-2-3.4 |  |
| Gmelinite (p. 345) R*. | 2.04-2.17 | $4 \cdot 5$ | Magnesite (p. 402) R. | $3 \cdot 3$ | 3.5-4.5 |
| Chabazite (p. 344) R.. | 2.08-2•19 | 4-5 | Cronstedtite (p. 357). | 3.35 | 2.5 |
| Levynite (p. 343) R.... | 2•1-2•16 | 4-4.5 | Dioptase (p. 301) R... | $3 \cdot 35$ | 5 |
| Zincaluminite (p. 440).. ? Tridymite (p. 288)... | ${ }_{2}^{2.26}$ | $2 \cdot 5-3$ | Rhodochrosite (p. 403) |  |  |
| ? Tridymite (p. 288). Hallite (p. 355) . . . | $2 \cdot 28-2 \cdot 33$ $2 \cdot 4$ |  | R Volborthite (p. 374) | $3 \cdot 4-3 \cdot 7$ $3 \cdot 55$ | ${ }_{3-3.5}^{3 \cdot 5}$ |
| Cancrinite (p. 317 ) | 2•4-2.5 | 5-6 | Bructite (p. 281) R | 3.6-4 |  |
| Chalcophyllite (p. 375). | 2.4-2.66 | 2 | Siderite (p. 403) R. | $3 \cdot 7-3 \cdot 9$ | $3 \cdot 5-4 \cdot 5$ |
| Nephelite (p. \%16). | 2.5-2.65 | 5•5-6 |  |  |  |

[^70]|  | Spec. Gravity | Hardness. |  | Spec. Gravity | Hardness. |
| :---: | :---: | :---: | :---: | :---: | :---: |
| Quartz (p. 284) R | 2.5-2.8 |  | Willemite (p. 3)1) R | 3.9-4.3 | $5 \cdot 5$ |
| Calctite (p. 398) R | 2.5-2.78 | 2.5-3.5 | Smitesonite (p. 404) R. | 4-4*45 |  |
| Microsommite (p. 317 ) . | $2 \cdot 60$ | 6 | Parisite (p. 408) | 4.35 | $4 \cdot 5$ |
| Alunite (p. 396) R..... | 2.6-2.75 | 3•5-4 | Covellite (p. 249) | 4.6 | 1-5-2 |
| Beryl (p 299) | 2.6-2.76 | 7•5-8 | Cerite (p. 340). | 4.91 | 55 |
| Penninite (p. 3jã) 1 | 2.6-2.85 | 2-2.5 | Fluocerite (p. 264) | 4.7 | 4-5 |
| Catapleiite (p. 339). | $2 \cdot 8$ |  | Greenockite (p. 242) | 38-5 | 3-3.5 |
| Dolomire (p. 411) R. | 2.8-2.9 | 3.5-4 | Zincite (p. 266) | 5-4-5.7 | 4-4.5 |
| Eudialyte (p. 299) R. | 2.9-3 | $5 \cdot 5$ | Iodyrite (p. 260). | 5•5-5.7 | soft. |
| Tourmaline (p. 329) R. | 2.94-3.3 | $6 \cdot 5-7 \cdot 5$ | Proustite (p. 253) R. | 5-4-5.56 | $2-2 \cdot 5$ |
| Ankerite (p. 402) R... | $2 \cdot 95-3 \cdot 1$ | 3.5-4 | Pyrargyrite (p. 252) R | 5.\%-5.9 | 2-2.5 |
| Apatite (p. 364). | 2.9-3:25 | 5 | Schwartzembergite (p. |  |  |
| Phenacite (p. 301) R | 2.96-3 | 8 | 262) | $5 \cdot 7-6 \cdot 3$ | 2-2.5 |
| Seybertite (p. 358) | $3-3 \cdot 1$ | $4-5$ | Tysonite (p, 439)...... | $6 \cdot 13$ | 4 5-5 |
| Friedelite (p. 302) R. | $3 \cdot 07$ | $4 \cdot 75$ | Pyromorphite (p. 366). | 6.5-7.1 | 3.5-4 |
| Breunerite (p. 402) R | 3-3.2 | 4-4.5 | Vanadinite (p. \%67) | (6) $\cdot 7-7 \cdot 23$ | $\stackrel{2}{ }$ - ${ }^{-3}$ |
| Wurtzite (p. 24.2 ) | 3.98 | 3.5-4 | Mimetite (p. 366) | 7-7.25 | $3 \cdot 5$ |
| Corundum (p. 267) R. | 3.9-4 16 | 9 |  |  |  |

B. Lustre Metallic (and Submetallic).

|  | Spec. Gravity | Hardness. |  | Spec. Gravity | Hardness. |
| :---: | :---: | :---: | :---: | :---: | :---: |
| Graphite (p. 230) | 2-1-2.23 | 1-2 | Allemo | 613-62 | 3-3.5 |
| Chalcophanite (p. 283).. | $3 \cdot 91$ | $2 \cdot 5$ | Antimony (p. 227) R. | 6.6-6.7 | 3-3.5 |
| Pyrriotite (p. 241).... | 4-4-4 7 | $3 \cdot 5-45$ | Tedradymite (p. 233).. | 7.2-7.9 |  |
| Molybdenite (p. 233). | 4-4-4.5 | 1-1.5 | Niccolite (p. 242) | 7 $3-7 \cdot 7$ | 5-5.5 |
| Menaccanite (p. 269) $\boldsymbol{\Omega}$ | $4 \cdot 5-5$ | 5-6 | Breithauptite (p. 243). | 7.54 | $5 \cdot 5$ |
| Hematite (p. 263) R. . | 4-5-5.3 | 5.5-6.5 | Joseite (p. 2\%3). | 7.93 | soft. |
| Beyrichite (p. 241). | $4 \cdot 7$ | 3-3.5 | Wehrlite (p. 233) | $8 \cdot 44$ | 1-2 |
| Millerite (p. 241) R . | 4.6-5.65 | 8-3.5 | Cinnabar (p. 240) R | 9.0 | 2-2.5 |
| Pyrargyrite (p. 252) R | $5 \cdot 7-5 \cdot 9$ | 2-2 5 | Bismuth (p. 227).. | $9 \cdot 73$ | 2-2.5 |
| Arsenic (p. 2206) R. | 5•93 | $3 \cdot 5$ | Iridosmine (p. 224). | 19-3-21 | 6-7 |
| Tellurium (p. 227). | 6•1-6.3 | 2-2.5 |  |  |  |

The crystals of the following species are sometimes Pseudo-Hexagonal (sce pp. 96, 97, und 188-190) as a result of repeated twinning:

Aragonite, cerussite, chrysoberyl, jordanite, leadhillite, milarite, stephanite, strontianite, witherite, zinkenite.

The species of the mica group and most of those of the chlorite groups are also PseudoHexagonal, the true form (monoclinic) approximating very closely to that required by the hexagonal system.
IV. CRYSTALLIZATION ORTHORHOMBIC.
A. Lustre Unmetallic.

|  | Spec.Gravity | Hardness: |  | Spec. Gravity | Hardness. |
| :---: | :---: | :---: | :---: | :---: | :---: |
| Struvite (p. 37 | 1.65-1\% | 2 | Zoisite (p. 308) | 3•1-3.38 | (0-6.5 |
| Lecontite (p. 392). |  | 2-2:5 | Dufrenite (p. 378). | 3.2-3.4 | $3 \cdot 5-4$ |
| Aphthitalite (p. 390) | 1.73 | 3-3.5 | Calamine (p. 339). | 3 $16-3 \cdot 9$ | 4.5-5 |
| Mascagnite (p. $3: 12$ ). | 1.73 | 2-2.3 | ? Astrophyllite (p. 313). | $3 \cdot 32$ |  |
| Epsomite (p. 394). | 1.75 | 2-2.5 | Hyperstiene (p. 200). | $3 \cdot 99$ | 5-6 |
| Fauserite (p. 394) | $1 \cdot 89$ | 2-2.5 | Euchroite (p. 373)... | $3 \cdot 39$ | 3-5-4 |
| Nitre (p. 379). | $1 \cdot 94$ | 2 | Diaspore (p. 2 29). | 3-3-3 5 | 6.5-7 |
| Erythrosiderite (p. 261). |  |  | Chrysolite (p. 300) | $3 \cdot 3-3 \cdot 5$ | 6-7 |
| Newberyite (p. 432).... |  |  | Uranospinite (p. 379) | 345 | 2-3 |
| Goslarite (p. 395). | 2.04 | 2-2.5 | Orpiment (p. 231). | $3 \cdot 48$ | 1.5-2 |
| Sulphur (p. 228). | 2.07 | 1.5-2.5 | Guarinite (p. 336). | $3 \cdot 49$ | 6 |
| Natrolite (p. 342). | $2 \cdot 17-2 \cdot 25$ | 5-5.5 | Serpierite ( p .438 ) |  |  |
| ? Pilinite (p. 344). | $2 \cdots$ |  | Langite (p. 397) . . | $3 \cdot 5$ | 2-5-3 |
| ? Gismondite (p. 341) | 2.265 | 4.5 | Triphylite (p. 369).... | 3.54-3.6 | 8 |
| Eudnophite (p. 344) | 2.27 | $5 \cdot 5$ | Topaz (p. 332) | 3.4-3.68 | 6 |
| Thomsonite (p. 342) | 2.3-2.4 | 5-5 5 | Ardennite (p. 310). | ${ }^{3 \cdot 62}$ | ${ }^{6-7}$ |
| Wavellite (p. 376). | ${ }_{3 \cdot 1-34}{ }^{2 \cdot 3}$ | 3.4 ${ }^{5} 5$ |  | $3 \cdot 1-3 \cdot 8$ $3 \cdot 4-8.8$ | ${ }_{7}^{4-5 \cdot 5}$ |
| Forsterite (p. 300). | 3.2-3.33 | $6-7$ | STAurolite (p. ejo) | -4 |  |


|  | Spec. Gravity | Hardness. |  | Spec. Gravity | Hardnes |
| :---: | :---: | :---: | :---: | :---: | :---: |
| Foresite (p. 347) |  |  | Uranocircite (p. 439 | 3 |  |
| Kaolinite (p. 351 ) | 2•4-2.63 | 1-2.5 | Chrysoberyl (p. 2i4).. | $3 \cdot 5-3 \cdot 84$ | 8.5 |
| Peganite (p. 378) | $2 \cdot 5$ | 3-3-5 | Strontianite (p. 406). | 3.6-3 71 | 3:5-4 |
| Milarite (p. 4:32). | 2.5-2.59 | 5.5-6 | Knebelite (p. 360) ... | $3 \cdot 71$ | $6 \cdot 5$ |
| Kiescrite (p. 391) | 2.52 | $2 \cdot 5$ | Libethentte (p. 373) | 3.6-3.3 |  |
| Iolite (p. 801) | 2.56-2.67 | 7-7.5 | Bromlite (p. 406) | 37 | 4-4.5 |
| Lanthantte (p. 410). | 2 6 -2.67 | 2.5-3 | Atacamite (p. 261) | 3-6-3.9 | 3-3.5 |
| TALC (p. 348).. | 2.6-2.8 | 1-1.5 | Claudetite (p. 284). | $3 \cdot 85$ |  |
| Aspidolite (p.312). | $2 \cdot 72$ | 1-2 | Hortonolite (p. S00) | 3.91 | 6.5 |
| Pyrophyllite (p. 349).. | 2•75-2.9 | 1-2 | Celestite (p. 388) | 8.9-3.98 | 3-3.5 |
| Phlogopite (p. 312)... | 2.78-2.85 | $2 \cdot 5-3$ | Rœpperite (p. 300). | 3.88-4.08 | 5•5-6 |
| Haidingerite (p. 371) | $2 \cdot 85$ | 1.5-2.5 | Sternbergite (p. 240) | 4.21 | 1-1.5 |
| $\mathrm{Prehnite}^{\text {(p. }}$ 340) | 2.8-2.9 | 6-6.5 | Cervantite (p. 284).. | 4.08 | 4-5 |
| Strengite (p. 437 ) | $2 \cdot 87$ | 3-4 | Tephroite (p. 300) | 4-4 12 | $5 \cdot 5$ |
| Aragonite (p. 40.5 | 2.93 | 3.5-4 | Brookite (p. 2\%\%) | 4.03-4*23 | 5.5-6 |
| Anifybrite (p. 389) | 2.9-2.98 | 3-3-5 | Göthite (p. 2E0) | 4-4.4 | $5-5 \cdot 5$ |
| Herderite (p. 370). | 2.98 | 5 | Olivenite (p. 373) | $4 \cdot 1-4 \cdot 4$ |  |
| Villarsite (p. 34 ) ) | $2 \cdot 99$ | $4-5$ | Witherite (p. 406 | $4 \cdot 3$ | 3-3•75 |
| Fluellite (p. 264) |  | 3 | Barite (p. 38\%). | $4 \cdot 3-4 \cdot 7$ | 2.5-3 |
| Danburite (pi). 311, 424) | 3 | 7-7.25 | Moly'dite (p. 284) | $4 \cdot 5$ | 1-2 |
| Manganocalcite (p. 406). | 3.04 | 4-5 | Euxenite (p. 262 ) | 4.6-5 | 6.5 |
| Diaclasite (p. 291). | $3 \cdot 05$ | 3.5-4 | Polymignite (p. 362 | 4.7-4.85 | 6.5 |
| Kupfferite (p. 298) | $3 \cdot 08$ | $5 \cdot 5$ | Polycrase (p. \%62) |  | 5.5 |
| Seybertite ( $\mathrm{p}, 358$ ) | $3-3 \cdot 1$ | 4-5 |  | 4.9-5•14 | 5-6 |
| Tyrolite (p. 3i4)... | 3-3-1 | 1-2 | Cotunnite (p. 261) | 5•24 | soft. |
| Reddingite (p. 435) | $3 \cdot 10$ | 3-3.5 | Valentinite (p. 28 | 5.57 | $\underset{2.5}{2 \cdot 5-3}$ |
| Autunite (p. 379)....) | 3.05-3•19 | 2-2.5 | Descloizite (p. 367) | ${ }^{5} 8.84$ | $3 \cdot 5$ |
| Anthophyliste (p. 295). | $3 \cdot 1-3 \cdot 2$ | $5 \cdot 5$ | Pucherite (p. 367) | 5.91 |  |
| Andalusite (p. 331) Humite (p. 32\%) | $3 \cdot 1-3 \cdot 2$ $3 \cdot 1-3 \cdot 24$ | ${ }^{7} 5$ | Anglesite (p. 389) | $6 \cdot 1-6 \cdot 89$ $6 \cdot 19$ | 2•75-3 |
| Monticellite (p. 3000 | ${ }_{3-3 \cdot 25}$ | ${ }^{6-5} 5$ | Leadillitite (p. 390) | 6.26-6.44 | $2 \cdot 5$ |
| Fosphorite (p. 423). | $3 \cdot 13$ | 5 | Cerussite (p. 407) | 6.48 | 3-3-5 |
| Childrenite (p. 377) | 3.18-3.24 | 4.5-5 | Nadorite (p. \%70) | $7 \cdot 02$ |  |
| Evstatite (p. 290). | 3-1-3 3 | 5.5 | Mendipite (p. 262). | 7-7•1 | 2•5-3 |

B. Lustre Metallic (and Submetallic).

|  | \|Spec. Gravity | Hardness.\| |  | Spec. Gravity | Hardness. |
| :---: | :---: | :---: | :---: | :---: | :---: |
| Ilvaite (p. 309) | $3 \cdot 7-4 \cdot 2$ | 5•5-6 | Jamesonite (p. 251) | 5.5-5.8 | 2-3 |
| Manganite (p. 280). | $4 \cdot 2-4 \cdot 4$ |  | Chalcocite (p. 239). | 5 5-5.8 | 2 5-3 |
| Chalcostibite (p. 250) | $4 \cdot 35-5$ | 3-4 | Columbite (p. 360). | 5.4-6.5 |  |
| Evargite (p. 257). | $4 \cdot 44$ | 3 | Bournonite (p. 253) | 5.7-5.9 | 2.5-3 |
| Epigenite (p. 253) |  | $3 \cdot 5$ | Diaphorite (p. 2n2). | $5 \cdot 90$ | 2.5-3 |
| Spathiopyrite (p. 216). | 4.5 | 6-7 | Glaucodot (p. 248) |  |  |
| Stibnite (p. 232). | $4 \cdot 53$ | 2 | Aikinite (p. 254). | $6 \cdot 16.8$ | 2-2.5 |
| Famatinite (p. 258). | $4 \cdot 57$ | $3 \cdot 5$ | Polybasite (p. 257 ). | 621 |  |
| Klaprotholite (p. 251) | $4 \cdot 6$ | $2 \cdot 5$ | Stephanite (p. 256). | 627 | 2-2.5 |
| Marcasite (p. 247 ) | 4.7-4.85 | $6-8.5$ | Stromeyerite (p. 240). | 6.2-6.3 | 2.5-3 |
| Livingstonite (p. 232). | $4 \cdot 81$ | 2 | Wolfachite (p. 247). | $6 \cdot 37$ |  |
| Stylotypite (p. 254) | $4 \cdot 79$ | 3 | Arsenopyrite (p. 247). | $6 \cdot 6 \cdot 4$ | 5'5-6 |
| Pyrolusite (p. 2i8) | $4 \cdot 82$ | 2-2.5 | Jordanite (p. 251). |  |  |
| Wittichenite (p. 254 ) | 5 | $3 \cdot 5$ | Geocronite (p. $25 \%$ ) | 6.4-6.6 | 2-3 |
| Guejarite (p. 428). | $5 \cdot 03$ | $3 \cdot 3$ | Alloclasite (p. 248). | 6.6 | $4 \cdot 5$ |
| Guanajuatite (p. 233) | $5 \cdot 15$ |  | Bismuthintte (p. 232). | 6.4-7.2 |  |
| Emplectite (p. 250) | 5•1-5•26 | 22.5 | Leucopyrite (p.248) | 6.2-7.3 | 5-5.5 |
| Zinkenite (p. 250$)$. | $5 \cdot 35$ | 3-3 5 | Löllingite (p.248).. | 6.8-8.7 |  |
| Sartorite (p. 200 ). | $5 \cdot 39$ |  | Acanthite (p. 239). | 7-16-7/3 |  |
| Samarskite (p. 361).. | 5-45-5.7 | 5•5-6 | Tantalite (p. 359) |  | 6-6.5 |
| Dufrenoysite (p. 251). | $5 \cdot 5-5 \cdot 6$ | 3 | Hessite (p. 238). | 8.3-8.6 | $2-3 \cdot 5$ |
| Yttrotantalite (p. 361 ).................... | 5-4-5.9 | 5-5.5 | Krennerite (p. 430) <br> Dysciansite (p. 234) | 9-4-9•8 | 3-5-4 |

CRYSTALLIZATION MONOCLINIC.
a. Lustre Unmetallic.

|  | Spec. Gravity | Hardness. |  | Spec. Gravity | Hardness |
| :---: | :---: | :---: | :---: | :---: | :---: |
| Natron (p. 409) | $1 \cdot 42$ | 1-1.5 | Wagnerite (p. 368) | $3 \cdot 07$ | 5-5.5 |
| Mirabilite (p. 392) | $1 \cdot 48$ | 1.5-2 | Köttigite (p. 372 ). | $3 \cdot 1$ | 2.5-3 |
| Borax (p. 381) | 1.72 | 2-2.5 | Ludlamite (p. 372 ) | $3 \cdot 12$ | $3 \cdot 5$ |
| Copperas (p. 394) | 1-8-2.2 | 2-2.5 | Spodumene (p. 295). | 3-1-3.19 | 6.5-7 |
| Gay-Lussite (p. 409). . | 1.9-1.99 | 2-3 | Lazulite (p. 375). . | 3-312 | 5-6 |
| Botryogen (p. 395)... | $2 \cdot 04$ | 2-2.5 | Euclase (p. 333). |  | $7 \cdot 5$ |
| Whewellite (p. 412). |  | 2.5-3 | Herrengrundite (p. 428) | $3 \cdot 13$ | $2 \cdot 5$ |
| Trona (p. 408). | $2 \cdot 11$ | 2.5-3 | Johannite (p. 397). | $3 \cdot 19$ | 2-2.5 |
| Hydromagnesite (p.409) | 2.14-2.18 | $3 \cdot 5$ | Chondrodite (p. 327). | 3•1-3•24 | 6-6.5 |
| Scolecite (p. 343). ... | $2 \cdot 1-2 \cdot 4$ | 5-5.5 | Clinohumite (p. 328). . | 3-1-3 24 | 6-6.5 |
| Stilbite (pp. 316, 437) | 2•09-2•2 | 3-5-4 | Fibrolite (p. 331). | $3 \cdot 2-3 \cdot 3$ | 6-7 |
| Phillipsite (pp. 345, | $2 \cdot 20$ | 4-4.5 | Allanite (p. 308).. | 3-4.2 | 5-5-6 |
| Heulandite (p. 347). . | $2 \cdot 2$ | 3.5-4 | Pyroxenr (p. 292) | 3-2-3.5 | 5-6 |
| GYpsum (p. 392). | 2.3-2.33 | 1-5-2 | Acmite (p. 294). | 3-2-3.53 |  |
| Gibbsite (p. 232) | 2•3-2.4 | 2.5-3.5 | Homilite (p. 429) | $3 \cdot 34$ | 4.5-5 |
| Syngenite (p. 394) | 2.25-2.6 | 2.5 | Dickinsonite (p. 425). | $3 \cdot 34$ | 3.5-4 |
| Laumontite (p. 338) | 2.25-2.36 | 3•5-4 | Piedmontite (p. 308). | 3.4-4 | 6.5 |
| Epistilbite (p. 347). | 2.25-2.36 | 4-4.5 | Fillowite (p. 427). | $3 \cdot 43$ | 4.5 |
| Brewsterite (p. 347). | $2 \cdot 43$ | $4 \cdot 5-5$ | Realgar (p. 231) | 3•4-3.6 | 1.5-2 |
| Petalite (p. 295). | 2-4-2. 5 | 6-6.5 | Titanite (p. 335). | 3-4-3.56 | 5-5.5 |
| Harmotome (p. 346). | $2 \cdot 45$ | $4 \cdot 5$ | ※girite (p. 294). | $3 \cdot 45-3 \cdot 6$ | 5•5-6 |
| Orthoclase (p. 32J). | 2.4-2.6 | 66.5 | Keilhauite (p. 3®6) | $3 \cdot 7$ |  |
| Vivianite (p. 371). | 2.58-2.68 | 1.5-2 | Azurite (p. 411). | 3.5-3.83 | 3•5-4 |
| Ripidolite (p. 356). | 2.6-2.8 | 2-2.5 | BArytocalcite (p. 408) | 3•64-3.66 |  |
| Pectolite (p. 337). | 2.65-2.8 |  | Triploidite (p. 439).... | 3.7 | 4•5-5 |
| Pharmacolite (p. 370) | 2.6-2.73 | 2-2.5 | Chalcomenite (p.422). . | $3 \cdot 76$ |  |
| Glauberite (p. 391)... | 2.6-2.85 | 2-5-3 | Malachite (p. 411). | 3•7-4.01 | 3•5-4 |
| Biotite (p. 312), LepiDolite and other |  |  | Brochantite (p. 396). Trögerite (p. 379)..... | $\begin{aligned} & 3 \cdot 8-3 \cdot 9 \\ & 3 \cdot 96 \end{aligned}$ | 3•5-4 |
| Micas. | 2.7-3.1 | 2.5-3 | Durangite (p. 370) | $3 \cdot 95-4 \cdot 03$ |  |
| Muscovite (p. 313) | $2 \cdot 7-3 \cdot 1$ | 2-2.5 | Gadolinite (p. 309) | 4-4.5 | 6.5-7 |
| Vaalite (p. 355 ) |  |  | Pyrostilpnite (p. 252). . | 4.2-4.25 |  |
| Wollastonite (p. 291) | 2.78-2.9 | 4.5-5 | Clinoclasite (p. 374). . | 4•2-4*36 | 2-5-3 |
| Datolite (p. 334). | 2.8-3 | 5-5.5 | Monazite (p. 368), Tur- |  |  |
| Hyalophane (p. 322). | 2-8-2.9 | 6-6.5 | nerite.. | 4.9-5.26 | 5-5.5 |
| Prochlorite (p. 357) | 2.8-2.96 | 1-2 | Miargyrite (p. 249) | 5.2-5.24 | $2-2 \cdot 5$ |
| Corundophilite (p. 35S). | $2 \cdot 9$ | $2 \cdot 5$ | Linaritr (p. 396). | 5-3-5.45 |  |
| Isoclasite (p. 3i3)..... | 2.92 | 1.5 | Vauquelinite (p. 386). | 5•5-5*8 | 2.5-3 |
| Cryolite (pp. 264, 424) | 2.9-3 | 2.5 | Laxmannite (p. 386)... | $5 \cdot 77$ |  |
| Thomsenolite (p. 438). |  |  | Walpurgite (p. 3i9). | 5.8 |  |
| Pachnolite (p. 265)... | 2.93-3 | 2.5-4 | Crocoite (p. 385).. | 5.9-6.1 | 2.5-3 |
| Leucophanite (pp. 300, |  |  | Lanarkite (p. 391). | 6.3-7 | 2-2.5 |
| 430)........ | 2.97 | 3.5-4 | Caledonite (p. 391) | 6.4 | 2.5-3 |
| Margarite (p. 35才). | $2 \cdot 99$ | 3:5-4.5 | Megabasite (p. 383). | $6 \cdot 45$ | $3 \cdot 5$ |
| Amphibole (p 296). | $\stackrel{2}{2 \cdot 9-3 \cdot 4}$ | 5-6 | Hübnerite (p. 383).. | $7 \cdot 14$ | 4.5 |
| Erythrite (p. 372).. | $2 \cdot 95$ | 2-2.5 |  |  |  |

B. Lustre Metallic (and Submetallic).

|  | Spec. Gravity | Hardness. |  | Spec. Gravity | Hardness, |
| :---: | :---: | :---: | :---: | :---: | :---: |
| Allanite (p. 308). | 3-4'2 | 5•5-6 | Meneghinite (p. 256).. | $6 \cdot 34$ | 2.5 |
| Clarite (p. 258)... | $4 \cdot 46$ | $3 \cdot 5$ | Freieslebenite (p.252) | 6-6.4 | 2-2.5 |
| Crednerite (p. 278 ) | $4 \cdot 9-5 \cdot 1$ | $4 \cdot 5$ | Wolframite (p. 383).. | 7-1-7.55 | 5-5.5 |
| Miargyrite (p. 249 ).. | $5 \cdot 2 \cdot 5 \cdot 4$ | ${ }_{2}^{2}-2.5$ | Sylvanite (p. 248).... | 8-8.3 | 1-5-2 |
| Plagionite (p. 251)... |  |  |  |  |  |

CRYSTALLIZATION TRICLINIC.

|  | Spec. Gravity | Hardness. |  | Spec. Gravity | Hardness. |
| :---: | :---: | :---: | :---: | :---: | :---: |
| Sassolite (p. 380). | 1.48 | 1 | Eggonite (p. 425). |  | 4-5 |
| Hannayite (p. 428). | 1.9 |  | Amblygonite (p. 369) | 3-3•11 | 6 |
| Chalcanthite (p. 394). | 2:21 | $2 \cdot 5$ | Fairfieldite (p. 426). | $3 \cdot 15$ | $3 \cdot 5$ |
| Wapplerite (p. 371). . | $2 \cdot 48$ | 2•2-5 | Axinite (p. 310). | $3 \cdot 27$ | $6 \cdot 5-7$ |
| Microcline (p. 326). | $2 \cdot 54$ |  | Babingtonite (p. 295).. | $3 \cdot 3-3 \cdot 37$ | 5-5-6 |
| Albite (p. 323). | 2.59-2.65 | 6-7 | Cyanite (p.382) | 3•4-3 7 | 5-7.25 |
| Oligoclase (p. 323).... | 2.65-2 69 | 6-7 | RHodonite (p. 294) | 3 4-3•7 | $5 \cdot 5-6 \cdot 5$ |
| Labradorite (p. 321). . | 2.67-2.76 | 6 | Veszelyite (p. 373). | $3 \cdot 5$ | 4 |
| Monetite (p. 432)... | $2 \cdot 75$ | $3 \cdot 5$ | Roselite (p. 372 ). . | :3•5-3:38 | $3 \cdot 5$ |
| Andesite (p. 322). | 2•61-2 74 | 6 | ? Brochantite (p. 396 . | $3 \cdot 8-3 \cdot 9$ | $3 \cdot 5.4$ |
| Anorthite (p. 321) | 2•66-2.78 | 6-7 | Pseudomalachite (p.374) | $4-4 \cdot 4$ | $4 \cdot 5-5$ |

## III. AUXILIARY TABLES.

A. Minerals whose Hardness is equal to, or greater than, 7 (Quartz='7).

|  | Hardness. | Cryst.* |  | Hardness. | Cryst. |
| :---: | :---: | :---: | :---: | :---: | :---: |
| Quartz (p. 284) | $\stackrel{7}{7}$ | III. (R) | Euclase (p. 333) | 7.5 | V. |
| Tridymite (p. 288) | 7 | III.? | Zircon (p. 314) | 7.5 | II. |
| Danburite (p. 311) | 7 | IV. | Andalusite (p. 331) | 7.5 | IV. |
| Boracite (crystals) (p. | 381) 7 | I. | Beryl (p. 299) | 7.5-8 | III. |
| Cyanite (p. 332 ) | 5-7.25 | VI. | Phenacite (p. 301) | 7•5-8 | III. (R) |
| Tourmaline (p. 329) | $6 \cdot 5-7 \cdot 5$ | III. (R) | Spinel (p. 271) | 8 | I. |
| Garnet (p. 302) | 6.5-7.5 | I. | Topaz (p. 332) | 8 | IV. |
| Iolite (p. 311) | 7-7.5 | IV. | Chrysoberyl (p. 274) | $8 \cdot 5$ | IV. |
| Staurolite (p. 336) | 7-7.5 | IV. | Corundum (p. 267) | 9 | III. (R) |
| Schorlomite (p. 337) | 7-7.5 | - | Diamond (p. 228) | 10 | I. |

The following minerals have hardness equal to $6-7$, or $6 \cdot 5-7$.
Iridosmine, III.-Cassiterite, II.; Diaspore, IV.; Chrysolite, IV.; Spodumene, V.; Epidote, V.; Ardennite, IV.; Gadolinite, V.; Fibrolite, V.; Feldspars, VI.; Axinite, VI.

## B. Unmetallic Minerals which are distinctly Foliated in some of their varieties.

1. Micaceous: easily separable into very thin laminæ, flexible to slightly brittle.
a. Micas (pp. 311 to 315): laminæ tough and elastic, except when they have undergone alteration; Anhydrous. Here are included the species: Phlogopite; Biotite; Muscovite; Lepidolite; Cryophyllite. These graduate into the

Hydro-micas (pp. 353, 354), in which the laminæ are inelastic and more or less brittle. Here belong: Fahlunite; Margarodite; Damourite; Paragonite; Cookeite; Euphyllite; Oellacherite, etc. ; and related to these, Margarite.

Lepidomelane is another mica (anhydrous or nearly so) whose folia are nearly inelastic. Astrophyllite is a micaceous member of the pyroxene family.
b. Chlorites ( 355 to 357 ): laminæ tough but mostly inelastic; hydrous ; color generally dark-green. Here are included: Penninite; Ripidolite; Prochlorite, etc. These are related to the Vermiculites ( p .355 ), in which the laminæ are less tough, being more or less brittle: Jefferisite; Pyrosclerite, etc.
c. Pyrophyllite. Talc, sometimes rather micaceous, laminæ soft, and somewhat greasy to the feel. Brucite is related in character, but differs chemically in being soluble in acids.
d. Torbernite,color deep-green; Autunite, color yellow to bright-green, laminæ brittle.

[^71]2. Not properly micaceous, though separable more or less easily into thin laminæ. Chloritoid (p. 353 ) and Seybertite ( p .358 ) are foliated, the laminæ not separating sasily. So also Bronzite, Hypersthene, Diallage, and Marmolite.

Gypsum sometimes occurs in soft, separable laminæ (var. Selenite), slightly flexible Zincite and Erythrite are sometimes foliated but not separable.
C. Unmetallic Minerals which in some of their varieties have a fibrous structure.

1. Easily separable into flexible fibres.

Asbestus (=amphibole) ; Crocidolite; Cbrysotile (=serpentine); Anthrosiderite.
2. Fibrous, not easily separable; structure graduating into columnar.

Anhydrous Silicates:-Enstatite; Wollastonite; Fibrolite; also, though more properly columnar in structure :-Cyanite; Epidote; Tourmaline.

Hydrous Silicates, Zeolites mostly :-Thomsonite; Okenite; Natrolite; Scolecite; Pectolite; Carpholite. Also some Serpentine.

Phosphates; Arsenates:-Wavellite; Cacoxenite; Pharmacolite; Dufrenite; Olivenite Vivianite; Pyromorphite.

Sulphates: Anhydrite; Barite; Celestite; Gypsum.
Carbonates:-Calcite; Rhodochrosite; Magnesite; Hydromagnesite; Aragonite; Malachite.

Also:-Brucite (nemalite); Sussexite; Ulexite.

## GENERAL INDEX TO MINERAL SPECIES

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[^0]:    * The vertical axis is throughout called c, see p. 53 .
    $\dagger$ It is more usual, and analytically more correct, to write this expression ra:nb:mc; but as the usual symbols take the form $m-n$, the order of the terms used here and elsewher is more convenient.

[^1]:    Models.-For clear illustration of the axes and axial ratius of planes it is well to have models of the axes made of rods of wood mortised and glued together at the crossing at centre. The rods may be haif an inch in diameter and 10 or 12 inches long; for the Isometric system, three equal rods, say 12 inches long; for the Tetragonal system, two of 12 inches for the lateral axes and one of 8 or 14 inches for the vertical ; for the Orthorhombic, one of 16 inches for axis $b$, one of 10 inches for axis $c$, and one of 14 inches for axis $a$. (Either axis may be made the vertical by way of change.)

    For the Clinometric systems, make a second model like that for the Orthorhombic system, but with the rods but loosely mortised and tied together, so as to admit of a little movement at centre. Then, the model when in its more natural position will be that of the orthorhombic system, the intersections being all rectangular. But by pushing the front rod $a$ down in the plane of $c a$, making it thus oblique to $c$ while at right angles to $b$, the model will represent the monoclinic axes; if all the intersections of the rods are oblique, the model will represent the axes of the Triclinic system.

    Now by taking a large piece of thick pasteboard, and placing it in different positions with reference to the three axes, the relations to the various planes may be readily iliustrated.

    Models of the various forms of crystals are also of the highest importance; and the best for general illustration are those made of plate glass, some of them having the positions of the uxes within indicated by threads, and others consisting of one form inside of another to show their mutual relations. Such glass models (first made by Professor Dana, in 1835, and recommended in the first edition of his Mineralogy) are now manufactured of great perfection at Siegen, in Germany.

    Pasteboard models, likewise useful aids to the study of crystallography, are easily made from the outlines of the faces of the various forms, which have been prepared by various authors.

    Models cut in hard wood representing the actual forms of the various mineral species are very valuable, when accurately made. They not only show the relations of different planes, but may also be advantageously used to give the stadent practice in the mathematical calcuiations of the axes and parameters, the angles being measured by him as on an actual crystal. Such models have the advantage of being of convenient size, and symmerically formed, which are conditions not often realized in the crystals furnished by nature.

[^2]:    It will be found a very valuable practice for the student to construct the figures of the successive crystalline formas in this way, laying off the proper lengths of the several axes and

[^3]:    * The word form has been freely used in the preceding pages; from this point on, however, it needs to be more exactly defined. In a crystallographic sense it includes all the "lanes geometrically possible. never loss than two, which have the same general symbol.

[^4]:    * For the relation of the axes thus lettored to those of Dana's System of Mineralogy and of other auth res, see 1. 53.

[^5]:    * Siuce the above paragraph was put into type, Des Cloizeaux has announced that an optical investigation by him has proved that humite crystals, of types II. and III., are really monorlinic, as suggested above. The figures are allowed to remain, however, since they illus trate the form which this metl od of hemihedrism would produce.

[^6]:    The method of construction of the circle of projection, for a given crystal, is in most cases very simple. The position of the crystal is commonly so taken that the prismatic zone is represented by the circumference of the circle, and the position of the normal-points of all prismatic planes lie uponit. The normal-points of the pinacoid planes are at $90^{\circ}$ from one another (the macropinacoid is not present on the crystal, f. 237). The two corresponding diameters, at right angles to each other, which are properly the projections of two great ciroles, intersect at the centre the normal-point of the basal plane, $O$; these diameters represent respectively the macrodome ( $m-\bar{i}$ ) and brachydome ( $m-\bar{\imath}$ ) zones of planes. The several positions of the normal-points of the prismatic planes are determined by laying off the sapplement angles of each with a protractor ; that of $i-2$ is $43^{\circ} 25^{\prime}$, and of $I, 62^{\circ} 8 \frac{1}{2}^{\prime}$, from the

[^7]:    * See also Supplementary Chapter, pp. 115 et seq.

[^8]:    An exception to the principle in regard to parallel axes is afforded in the case of hemihedral crystals, in some of which a revolution of $180^{\circ}$ has the effect of producing an apparently holohedral form, the axes of the parts revolved remaining parallel.

[^9]:    * A complete enumeration of the different methods of twinning observed under the different systems, with detailed descriptions and many figures, will be found in Vol. II. of RoseSadebeck's Crystallography (Angewandte Krystallographie, 284 pp ., 8 rc , Berlin, 1876).

[^10]:    * Reference must be made here to the discussion by Scacchi of the principle of "Polysym. metry." (Atti Accad. Napoli, $\left.\mathrm{i}_{4}, 1864.\right)$. See also Hirschwoald, Zur Kritik des Leucitsystems, Tsch. Min. Mitth., 18\%5, 22\%. See further the discussion on pp. 185 et seq.

[^11]:    * Die Krystalliten von Hermann Vogelsang. Bonn, 1875.

[^12]:    * The author is indebted to R. Fuess for the electrotypes from which this and the following figures ( $372 \mathrm{~A}, \mathrm{~B}, \mathrm{C}, \mathrm{D}$, also, f. 412c, D, ㄷ, F, H, K, L) have been printed.

[^13]:    * See Websky, Z. Kryst., iii., 241.

[^14]:    * See further on p. 173.

[^15]:    Baumhauer. Ueber Aetzfiguren und die Erscheinungen des Asterismus an Krystallen; Pogg. Ann. cxxxviii., 163 ; cxxxix., 349 ; cxl., 271 ; cxlv., 459 ; sliii., 621 ; Ber. Ak. München, 1875, 169.

    Daniel Quarterly Journal of Science, i., 24. 1816.
    Exner. An Lösungsfiguren in Krystallen; Ber. Ak. Wien, lxix., 6. 1874.
    Hirschwald. Aetzfiguren an Quarz-Krystallen; Pogg. cxxxvii., 548. 1869.
    Knop. Jahrb. Min., 1872, 785.
    Leydolt. Ueber Aetzungen; Ber. Ak. Wien, xv., 58; xix., 10.
    Pape. Ueber das Verwitterungs-Ellipsoid wasserhaltiger Krystalle; Pogg. exxiv., 329 : exxv., 513. 1865.

[^16]:    * See further on pd. 177 et sea.

[^17]:    Between these classes there are many cases of gradual transition in crystalline form, and, similarly and necessarily, in optical character. The line between uniaxial and biaxial crystals, for instance, cannot be considered a very sharply defined one.*

[^18]:    * It will be understood that the optic axis is always a direction, not a fixed line in the exystals.

[^19]:    * Uniaxial crystals which produce circular polarization exhibit interference figures which differ somewhat from those described. Some anomalies are mentioned on p. 158. See also pp. 185 et seq.

[^20]:    * See further on p. 180.
    + Almond oil, which has been decolorized by exposure to the light, is commonly employed.

[^21]:    * Zur Knnntniss der Feldspathbildung; Haarlem Soc. Verhandl., xxv., 1866.

[^22]:    * For a discussion of this subject in the light of recent (1882) investigations, see pp. 185 et seq.

[^23]:    *This subject has been investigated by Becquerel, Ann. Ch. Phys., III., lv., 5-119, 1859 ; Faster, Mitth. nat. Ges. Bern, 1867, 62; and Hahn, Zeitsch. Ges. nat. Wiss. Berlin, II., [. . . 1,131, 1874.

[^24]:    *For the full development of this` subject, see the works of Rosenbusch and Zirkeer (titles on p. 111.) ; also the following :

    Boricky, E. Elemente einer neuen chemisch-mikroskopischen Mineral- und Gesteinsanalyse, 72 pp .4 to, Prag, $187 \%$.

    Cohen, E. Sammlung von Mikrophotographieen zur Veranschaulichung der mikroskopishen Structur von Mineralien und Gesteinen, aufgenommen von J. Grimm in Oifenburg, 1, 2, 3, 4, 5 Lfg., Stuttgart, 1881-82.

    Doelter. Die Bestimmung der petrographisch wichtigeren Mineralien durch das Mikroskop ; Eine Anleitung zur mikroskop. Gesteins-Analyse, 36 pp. 8vo, Vienna, 1876.

    Fouqué, F. and Michel-Lévy, A. Minéralogic micrographique, roches éruptives Françaises, 509 pp . 4to, Paris, 1879.

    Rutley, F. The Study of Rocks, 319 pp .12 mo , London, 1879.
    Thoulet. Contributions à l'étude des propriétés physiques et chemiques des minéraux microscopiques, 77 pp. 8vo, Paris.

    Hawes, G. W. The Mineralogy and Lithology of New Hampshire (Geology of New Hampshire, vol. iii.), 262 pp .4 to, with 12 plates. Pages $8-18$ of this work give an excellent summary of microscopic methods of investigation, as applied to rocks and minerals.

[^25]:    *A memoir by Mallard (Bull. Soc. Min., v., 144, 1882) upon the effect of heat upon boracite crystals was received just as these pages were going to press. Mallard details the results of numerous experiments, and concludes that the effect of heat does not modify the form of the ellipsoid of elasticity, nor the position of the six different orientations which it can have ; it only modifies the choice made by each of the crystal sections between the six orientations. From this it is concluded that this ellipsoid is in fact characteristic of the crystalline réseau of the species, and that the apparent isometric symmetry is due to the method of grouping alluded to. Analogous results were obtained with crystals of potassium sulphate (orthorhombic, pseudo-hexagonal like aragonite), and the conclusion is drawn from this that a perfect analogy exists between the so-called pseudo-isometric crystals and the pseudo-hexagonal.

[^26]:    * Recent investigations have added a considerable number of supposed new elements to the list on the following page.

[^27]:    * By the determination of the specific heats of cerium, didymium, and lanthanum, Dr. Hillebrand has shown recently that the oxides of the three metals are sesquioxides $\left(\mathrm{Ce}_{2} \mathrm{O}_{3}\right.$, $\mathrm{Di}_{2} \mathrm{O}_{3}, \mathrm{La}_{2} \mathrm{O}_{3}$ ), and corresponding to them the atomic weights should be $\mathrm{Ce}=138, \mathrm{Di}=$ $144 \cdot 8, \mathrm{La}=139$. (Pogg. Ann., clviii., 71, 1876.)

[^28]:    * This relation was brought out by Prof. Dana in 1867 (Am. J. Sci., xliv.. 89, 252, 398), and it forms the basis of all the formulas, according to the new system, in Dana's System of Mineralogy, 1868. Prof. Cooke has discussed the same subject (Am. J. Sci., 1I., xlvii., 386, 1869), he calls the ratio, the Atomic Ratio; the latter term, however, is generally used in a different sense, hence the expression Quantivalent Ratio employed here.
    $\dagger$ Throughout this work the letter R, unless otherwise indicated, represents a bivolent metal, and Z either $\mathrm{Fe}, \mathrm{Al}, \mathrm{Gr}, \mathrm{Afn}$, where the quantivalence of the double atom is $8 x x$. In a few cases, to indicate further relations, the sign of the quantivalence is sometimes emploved

[^29]:    * The asterisk in this and similar cases indicates that the species is mentioned again in the Supplementary Chapter, pp. 420 to 440.

[^30]:    Comp.-According to Klaproth, Tellurium 92.55, iron 7.20, and gold 0.25.
    Pyr.-In the open tube fuses, giving a white sublimate of tellurous oxide, which B.B. fuses to colorless transparent drops. On charcoal fuses, volatilizes almost entirely, tinges the flame green, and gives a white coating of tellurous oxide.

    Obs.-Native tellurium occurs in Transylvania (whence the name Sylvanite) ; also at the Red Cloud mine, near Gold Hill, Boulder C'o., Colorado.

[^31]:    Comp.- $\mathrm{As}_{2} \mathrm{~S}_{3}=$ Sulphur 39, arsenic $61=100$.
    Pyr., etc.-In the closed tube, fuses, volatilizes, and gives a dark yellow sublimate; other reactions the same as under realgar. Dissolves in nitro-hydrochloric acid and caustic alkalies.

    Obs-Orpiment in small crystals is imbedded in clay at Tajowa, in Upper Hungary. It is asually in foliated and fibrous masses, and in this form is found at Kapnik, at Moldawa, and at Felsöbanya ; at Hall in the Tyrol it is found in gypsum ; at St. Gothard in dolomite ; a

[^32]:    * The species of this group contain as bases chiefly copner, lead, and silver. They can be mnst readily distinguished by their behavior before the blowpipe. Attention may be called to the group of lead sulphantim onites, zinkentte, plagionite, (jamesonite) boulangorite, meneyhinite, geocronice, for which the pyrognostics are nearly similar, and which are most surely wiatinguished by their specific gravity.

[^33]:    Comp. $-\mathrm{Pb}_{2} \mathrm{As}_{2} \mathrm{~S}_{5}$ (or $2 \mathrm{PbS}+2 \mathrm{As}_{2} \mathrm{~S}_{3}$ ) =Sulphur $22 \cdot 10$, arsenic $20 \cdot 72$, lead $57 \cdot 18=100$.

    Pyr., etc.-Easily fuses and gives a subli-
    mate of sulphur and arsenous sulphide; in

[^34]:    Comp.- $\mathrm{ZnO}=$ Oxygen $19 \cdot 74$, zinc $80 \cdot 26=100$; containing manganese as an unessential ingredient. The red color is due probably to the presence of manganese sesquioxide, certainly not to scales of hematite.

[^35]:    * The compounds here considered are sometimes regarded as salts of the acide, $\mathrm{H}_{2} \mathrm{ZFO}$, that is, as aluminates, ferrates, etc.

[^36]:    Var.-1. Ordinary, Tin-stone. In crystals and massive. G. of ordinary cryst. 6.96; of colorless, from Tipuani R., Bolivia, $6 \cdot 832$, Forbes. 2. Wood Tin (Holz-Zinn, Germ.). In botrvoidal and reniform shapes, concentric in structure, and radiated fibrous internally

[^37]:    Comp., Var.-Titanic oxide, $\mathrm{TiO}_{2}=$ Oxygen 39, titanium $61=100$. Sometitnes a lit cle iron is present.

    Pyr., etc.-B. B. infusible. With salt of phosphorus gives a colorless bead. which in R F essumes a violet color on cooling. Most varieties contain iron, and give a brownish-yellow or red bead in R.F., the violet only appearing after treatment of the bead with metallic tin on charcoal. Insoluble in acids; made soluble by fusion with an alkali or alkaline carbonate. The solution containing an excess of acid, with the addition of tin-foil, gives a beautiful violet-color when concentrated.

[^38]:    Comp., Var.-General formula $\mathrm{RSiO}_{3}$, as for pyroxene. Aluminum is present in most amphibole, and when so it usually replaces silicon. R may correspond to two or more of the basic elements $\mathrm{Mg}, \mathrm{Ca}, \mathrm{Fe}, \mathrm{Mn} . \mathrm{Na}_{2}, \mathrm{~K}_{2}, \mathrm{H}_{2}$; and R to Fl , Fe or Mn . Fe sometimes replaces silicon, like Al. Much amphibole, especially the aluminous, contains some fluorine. The base calcium is absent from some varieties, or nearly so.

    The varieties of amphibole are as numerous as those of pyroxene, and for the same reasons; and they lead in general to similar subdivisions

[^39]:    Comp.-Analyses vary. If it contains 2 p. c. water (Ramm.), and if $B_{2}$ replaces tl , then it is a unisilicate with the formula $\mathrm{R}_{7} \mathrm{R}_{3} \mathrm{Si}_{8} \mathrm{O}_{32}, \mathrm{R}=\mathrm{Fe}, \mathrm{Mn}, \mathrm{Ca}, \mathrm{Mg}$, and $\mathrm{K}_{2}$, while $\mathrm{R}=\mathrm{B}_{2}$, Al $\left(\mathbf{B}_{2}: \mathrm{Al}=1: 2\right)$. Analysis (Ramm.), Oisans. Dauphiné, $\mathrm{SiO}_{2} 43 \cdot 46, \mathrm{~B}_{2} \mathrm{O}_{3} 5.61, \mathrm{AlO}_{3} 16.33$, $\mathrm{FeO}_{3} 2 \cdot 80, \mathrm{FeO} 6 \cdot 78$, $\mathrm{MnO} 2 \cdot 62, \mathrm{CaO} 20 \cdot 19$. $\mathrm{MgO} 1 \cdot 73, \mathrm{~K}_{2} \mathrm{O} \quad 0 \cdot 11, \mathrm{H}_{2} \mathrm{O} 1 \cdot 45=101 \cdot 08$.

    Pyr., etc.-B. 13. fuses readily with intumescence, imparts a pale green color to the O.F., and fuses at 2 to a dark green to black glass; with borax in O.F. gives an amethystine dead (manganese), which in R.F. becomes yellow (iron). Fused with a mixture of potassium bisul-

[^40]:    A variation of ong or two degrees from the above mean angles was observed in some specimens. See further on p. 426.

[^41]:    Comp., Var.-Q. ratio for $\mathrm{R}: \mathrm{Al}: \mathrm{Si}=1: 3: 6$, but varying somewhat (see p. 319). Formula $\mathrm{RAlSi}_{3} \mathrm{O}_{10} ;$ here $\mathrm{R}=\mathrm{Ca}$ and $\mathrm{Na}_{2}$. The atomic ratio for $\mathrm{Na}: \mathrm{Ca}=2: 3$ generally, this corresponds to Silica $52 \cdot 9$, alumina $30 \cdot 3$, lime $12 \cdot 3$, soda $4 \cdot 5=100$.
    Var. 1. Cieavable. (a) Well crystallized to (b) massive. Play of colcrs either wanting, sa

[^42]:    * Vom Rath has recently shown this to be the true method of twinning in this case, and hence that the explazation of Rose (given on p. 101) is incorrect.

[^43]:    Comp.-Q. ratio for $\mathrm{H}: \mathrm{Be}: \mathrm{Al}: \mathrm{Si}=1: 2: 3: 4$, for $\mathrm{R}: \mathrm{Si}=3: 2$ ( $\mathrm{H}_{2}=\mathrm{R}$, and $3 \mathrm{R}=\mathrm{Al}$ ), formula, $\mathrm{H}_{2} \mathrm{Be}_{2} \mathrm{AlSi}_{2} \mathrm{O}_{10}=$ Silica $41 \cdot 20$, alumina $35 \cdot 22$, glucina $17 \cdot 39$, water $6 \cdot 19=100$.
    Pyr., etc.-In the closed tube, when strongly ignited, B.B. gives off water (Damour). B.B. in the forceps cracks and whitens, throws out points, and fuses at 5.5 to a white enamel. Not acted on by acids.
    Obs.-Occurs in Brazil, at Villa Rica; in southern Ural, near the river Sanarka.

[^44]:    * These relations were brought out by Cooke. Proc. Amer. Acad., Bostcn, 187t, 35 ; ibid., 1875, 453.

[^45]:    Comp.- $\mathrm{FeAs}_{2} \mathrm{O}_{8}+4 \mathrm{aq}=$ Arsenic pentoxide $49 \cdot 8$, iron sesquioxide $34 \cdot 6$, water $15 \cdot 6=100$.
    Pyr., etc.-In the closed tube yields neutral water and turns yellow. B.B fuses easily, coloring the flame blue. B.B. on charcoal gives arsenical fumes, and with soda a black magnetic scoria. With the fluxes reacts for iron. Soluble in hydrochloric acid.

[^46]:    Comp. $-\mathrm{Fe}_{4} \mathrm{As}_{6} \mathrm{O}_{27}, 15 \mathrm{aq}=3 \mathrm{FeAs}_{2} \mathrm{O}_{8}+\mathrm{H}_{6} \mathrm{FeO}_{6}+12 \mathrm{H}_{2} \mathrm{O}=$ Arsenic pentoxide $43 \cdot 13$, iron sesquiozide $40 \cdot 00$, water $16 \cdot 87=100$.
    Pyr., etc.-Same as for scorodite.
    Obs.--Formerly obtained at the mines of Wheal Gorland, Wheal Unity, and Carharrack, in Cornwall; now found at Burdle Gill in Cumberland; in minute tetrahedral crystals ai Wheal Jane; also in Australia; at St. Leouard in France and at Suaneeberg and Schwar. venberg in Saxony.

[^47]:    Comp.-Q. ratio for $\mathrm{R}: \mathrm{U}: \mathrm{P}: \mathrm{O}=1: 6: 5: 8$; formula $\mathrm{CuU}_{2} \mathrm{P}_{2} \mathrm{O}_{12}+8 \mathrm{aq}=2\left(\mathrm{UO}_{2}\right)_{3} \mathrm{P}_{2} \mathrm{O}_{8}$ $+\mathrm{Cu}_{3} \mathrm{P}_{2} \mathrm{O}_{8}+24 \mathrm{aq}$. The formula requires: Phosphorus pentoxide $15 \cdot 1$, uranium trioxide $61 \cdot 2$, copper oxide $8 \cdot 4$, water $15 \cdot 3=100$.

    Pyr., etc.-In the closed tube yields water. In the forceps fuses at 2.5 to a blackish mass, and colors the flame green. With salt of phosphorus gives a green bead, which with tin on charcoal becomes on cooling opaque red (copper). With soda on charcoal gives a globule of copper. Affords a phosphide with the sodium test. Soluble in nitric acid.
    Obs.-Gunnis Lake, Tincroft and Wheal Buller, near Redrutb, and elsewhere in Cornwall. Found also at Johanngeorgenstadt, Eibenstock, and Schneeberg, in Saxony ; in Bohemia, at Joachimsthal and Zinnwald; in Belgium, at Vielsalm.

    Both this species and the autunite have gone under the common name of uranite; the former also as Copper-uranite, the latter Lime-uranite.

[^48]:    Comp. $-\mathrm{PbSO}_{4}=$ Sulphur trioxide $26 \cdot 4$, lead oxide $73 \cdot 6=100$.
    Pyr., etc.-B.B. decrepitates, fuses in the flame of a candle (F. = 1.5). On charcoal in $\mathbf{0}$. F. fuses to a clear pearl, which on cooling becomes milk-white ; in R.F. is reduced with effervescence to metallic lead. With soda on charcoal in R.F. gives metallic lead, and the soda is ahsorbed by the coal ; when the surface of the coal is removed and placed on bright silves and moistened with water it tarnishes the metal black. Difficultly soluble in nitric acid.

[^49]:    Comp.-CuSO ${ }_{4}+5 \mathrm{aq}=$ Sulphur trioxide $32 \cdot 1$, copper oxide $31 \cdot 8$, water $36 \cdot 1=100$.
    Pyr., etc.-In the closed tube yields water, and at a higher temperature sulphuric acid.
    B.B. with soda on charcoal yields metallic copper. With the fluxes reacts for copper. Solu-
    ble in water; a drop of the solution placed on a surface of iron coats it with metallic copper.
    Obs. - Blue vitriol is found in waters issuing from mines, and in connection with zocks containing chalcopyrite, by the alteration of which it is formed. Some of its foreign localitien

[^50]:    Comp. $-\mathrm{MnCO}_{3}=$ Carbon dioxide $38 \cdot 3$, manganese protoxide $61 \cdot \%$; but part of the manganese usually replaced by calcium, and often also by magnesium or iron; and sometimes by oobalt.

    Pyr., etc.-B.B. changes to gray, brown, and black, and decrepitates strongly, but is infusible. With salt of phosphorus and borax in O.F. gives an amethystine-colored bead in R.F. becomes colorless. With soda on platinum foil a bluish-green manganate. Dissolves with effervescence in warm hydrochloric acid. On exposure to the air changes to brown, and some bright rose-red varieties become paler.

    Obs.-Occurs commonly in veins along with ores of silver, lead, and copper, and with other ores of manganese. Found at Schemuitz and Kapnik in Hungary ; Nagyag in Transylvania; near Elbingerode in the Harz; at Freiberg in Saxony.

    Occurs in New Jersey, at Mine Hill, Franklin Furnace. Abundant at the silver mines of Austin, Nevada; at Placentia Bay, Newfoundland.

    Named rhod chrosite from $\delta \delta \delta o \nu$, a rose, and $\chi \rho \omega \sigma t s$, color; and dialogite, from $\delta \leqslant a \lambda o \gamma \eta$, doubt.

[^51]:    Var.-1. Ordinary. (a) Crystallized in simple or compound crystals, the latter much the most common; often in radiating groups of acicular crystals. (b) Columnar; a fine fibrons variety with silky lustre is called satin spar. (c) Massive. Stalactitic or stalagmitic (either compact or fibrous in structure), as with calcite; Sprudelstein is stalactitic from Carlsbad. Coralloidal; in groupings of delicate interlacing and coalescing stems, of a snow-white color, and looking a little like coral.
    Comp.- $\mathrm{CaCO}_{3}$, like calcite,$=$ Carbon dioxide 44 , lime $56=100$.
    Pyr., etc.-B.B. whitens and falls to pieces, and sometimes, when containing strontia, imparts a more invensely red color to the flame than lime; otherwise reacts like calcite.
    Diff.-See calcite, p. 401.
    Obs.-The most common repositories of aragonite are beds of gypsum, beds of iron ore (where it occurs in coralloidal forms, and is denominated flos-ferri, "flower of iron," Eisenblüthe, Germ.), basalt, and trap rock; occasionally it occurs in lavas. It is often associated with copper and pyrite, galenite, and malachite.
    First discovered in Aragon, Spain (whence 1ts name), at Molina and Valencia. Since found at Bilin in Bohemia; at Herrengrund in Hungary, f. 738; at Baumgarten in Silesia;

[^52]:    *For fuller descriptions of new species, references to original papers, etc., see Appendix III. (1882), System of Mineralogy.

[^53]:    Berzelite.-This arsenate from Långban, Sweden, is isometric according to Sjögren ; honey to sulphur yellow, lustre resinous. Lindgren regards the ortho-arsenate of calcium and magnesium, anisotrope, of the same locality, as distinct, and says that earlier descriptions of berzeliite belong to it.

[^54]:    Newberyite, vom Rath. - In rather large tabular orthorhombic crystals. Composition $\mathrm{Mg}_{2} \mathrm{H}_{2} \mathrm{P}_{2} \mathrm{O}_{8}+6$ aq. From the guano of the Skipton Caves, Victoria.

[^55]:    * The symbol is written here in this order to correspond with the i $h k l$ ) of Miller ; on page 10, and subsequently, the reverse order $\frac{3}{2} c: \frac{3}{2} b: a$ was adopted for the sake of unilormity with Naumann's abbreviated symbols.

[^56]:    * In general the indices of any individual plane are written ( $k l l$ ), whereas the general symbol [ $h k l$ ] indicates all the planes belonging to the form, varying in number in the different systems; thus, in this system, $\lceil 100\rceil$ is the general symbol for the six sirilar planes of the cube.

[^57]:    * The order of the terms in the symbols below is made to correspond to that of the indices $k, k, l$.

[^58]:    * The same lettering is employed here as in the early part of this work; it differs from that of Miller in that with him $a$ is the macrodiagonal, and $b$ the brachydiagonal axis, Following Groth, and later writers (Bauerman, ete.), the macropinacoid has the symbol ( 1091 , and the brachypinacoid the symbol ( 010 ); similarly the macrodomes are in general
    

[^59]:    * This is true since the axial angles are right angles. In the Monoclinic System two of the axial intersections are perpendicular, and they are sufficient to allow of the determina tion of the point T, as above. In the Triclinic System the method needs to be slightly modified.

[^60]:    * The catalogue is essentially the same as that published in the 5th Edition of Dana's Sys tem of Mineralogy, 1868. The names of a considerable number of new localities have been added, however, which have been derived from various printed sources, and also from private contributions from Prof. G. J. Brush, Mr. G. W. Hawes, Mr. J. Willcox, and others,

    See further on pp. 503 to 508.

[^61]:    Acwortil-Beryl!! mica! tourmaline, feldspar, albite, rose quartz, columbite! cyanite, autunite.

    Alstead.-Mica! ! albite, black tourmaline, molybdenite, andalusite, staurolite.
    Amierst. - Vesuvianite, yellow garnet, pargasite, calcite, amethyst, magnetite.
    Bartlett. - Magnetite, hematite, brown iron ore in large veins near Jackson (on "Bald
    face mountain "), quartz crystals, smoky quartz.
    Batir.-Galenite, chalcopyrite.
    BedFord. -Tremolite, epidote, graphite, mica, tourmaline, alum, quartz.
    Bellows Falls.-Cyanite, staurolite, wavellite.
    Bristol. -Graphite.

[^62]:    * See also Pumpelly ; on the Paragenesis of copper and its associate minerals on Lake Superior Am. J. Sci., III $, ~ x, ~ 17$.

[^63]:    - See the Catalogue of Minerals of Colorado by J. Alden Smith.

[^64]:    *For a more complete list of localities in New Brunswick, Nova Scotia, and Newfound land, see catalogue by O. C. Marsh, Am. J. Sci., II. xxxv. 210, 1863.

[^65]:    * For a complete list of the minerals and mineral localities of North Carolina, see Geology of North Carolina, vol. II., chap. I.. Mineralogy by F. A. Genth and W. C. Kerr, with notes by W. E. Hidden; 122 pp., 8vo, Raleigh, 1881.

[^66]:    *See Notes on the Mineralogy of Missouri, by Alexander V. Leonhard, St. Louis, 1882.

[^67]:    * The author is indebted for the following notes, as also for others under Arizona and Montana, to Prof. B. Silliman.

[^68]:    * Nitric acid is needed only in the case of lead salts (cerussite, phosgenite, leadhillite). In addition to the proper carbonates, also leadhillite and cancrinite effervesce with acid, and with many minerals effervescense may be caused by a mechanical admixture of calcite (e.g., wollastonite), or some other carbonate (e.g., lanarkite).

[^69]:    * Note the precaution on p. 209 ; it may be remarked in addition that, in the case of a sulphate, the reaction is generally so decided that there can be no ambiguity, even when the gas contains a little sulphur. In all cases the soda on charcoal should be first tested alone

[^70]:    * Species, after whose names an $R$ is written, belong to the Rhombohedral Division.

[^71]:    * Here, as elsewhere, I. = Isometric ; II. = Tetragonal; III. = Hexagonal; IV.=Ortho rhombic; $\mathrm{V}=$ Monoclinic; VI. $=$ Triclinic.

